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Air Quality Monitoring in Alberta 1996

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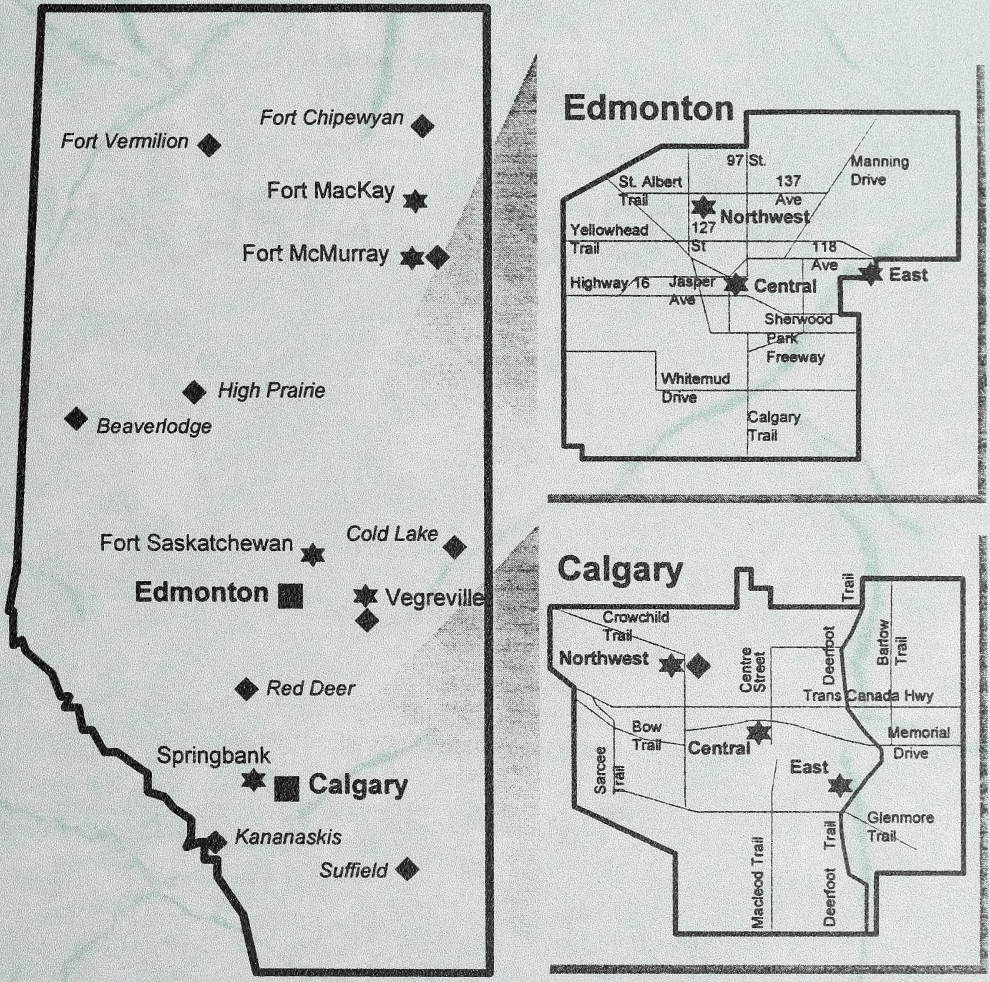
DETAILED REPORT



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AIR QUALITY MONITORING IN ALBERTA

1996 DETAILED REPORT

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Air Issues and Monitoring Branch
Chemicals Assessment and Management Division
Alberta Environmental Protection

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This report is one in a series of air quality annual reports produced by Alberta Environmental Protection for 1996. The following air quality annual reports are available for 1996:

Air Quality Monitoring in Alberta: 1996 Summary Report;
Air Quality Monitoring in Alberta: 1996 Detailed Report, and
Air Quality Monitoring in Alberta: 1996 Data Report.

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SUMMARY

In 1996, the Alberta Environmental Protection air quality monitoring program consisted of:

- **11 continuous stations** that measured hourly concentrations of air chemicals such as carbon monoxide, carbon dioxide, dust and smoke (the coefficient of haze), hydrogen sulphide, oxides of nitrogen (including nitric oxide and nitrogen dioxide), ozone, sulphur dioxide, total hydrocarbons and inhalable particulates;
- **8 intermittent stations** that collected 24-hour measurements of suspended particulates, polycyclic aromatic hydrocarbons, sulphates and nitrates;
- **2 static networks** that monitored monthly loadings of total sulphation and hydrogen sulphide; and
- **11 precipitation quality stations** that collected weekly rain and snow samples which were analyzed for pH and deposition of major cations and anions.

The Index of the Quality of the Air

The Index of the Quality of the Air (IQUA) is a method of reporting air quality in terms that are easy to understand for the general public. This index associates concentrations of five major air pollutants to federal and provincial air quality objectives. Air quality is reported as Good, Fair, Poor or Very Poor.

In 1996, the air quality at Alberta Environmental Protection stations was Good at least 94% of the time on an annual basis. The frequency of Good air quality readings ranged from 94.5% at the Fort Saskatchewan station to 99.9% at the Calgary Central station. Fair air quality was reported to occur 5.5% of the time at the Fort Saskatchewan station, 2.8% of the time at the Calgary Northwest station, and less than 2% of the time at the remaining stations. The IQUA was in the Poor category for 2 hours at the Edmonton Northwest station, for 3 hours at the Calgary East station and for 4 hours at the Fort Saskatchewan station. Very Poor air quality was not reported at any monitoring stations in 1996.

Carbon Monoxide

The 1-hour guideline for carbon monoxide was exceeded twice at the Calgary Central monitoring station. The 8-hour guideline was exceeded 2 times at the Edmonton Northwest station, and 4 times at both the Calgary Central and Calgary East stations. Exceedances of the guidelines were caused by the combination of vehicle exhaust emissions with strong temperature inversions and light winds. Based on data since 1975, a downward trend in carbon monoxide concentrations is evident at the Edmonton Central station, Edmonton Northwest station, all of the Calgary stations, and the Fort Saskatchewan station (since 1982).

Dust and Smoke

The monthly guideline for dust and smoke (the coefficient of haze) was exceeded at the Calgary East monitoring station in February and December. These exceedances were due to vehicle exhaust emissions and traffic movement during stagnant weather conditions (strong temperature inversions with light winds). A small increase in annual average dust and smoke values is indicated at the Edmonton East and Fort McMurray monitoring stations.

Ozone

The 1-hour guideline for ozone was exceeded twice at the Edmonton Northwest station and 3 times each at both the Fort Saskatchewan and Royal Park monitoring stations. All of these exceedances occurred on August afternoons during hot weather conditions. These exceedances were likely due to the combination of ozone generated from natural sources with the incremental contribution of ozone produced by human sources (ozone produced from oxides of nitrogen and hydrocarbons from automobiles and industry).

The 24-hour guideline for ozone was exceeded most frequently at rural and small urban monitoring stations. such as Royal Park (252 days), Fort Saskatchewan (181 days) and the Springbank Airport (137 days). This guideline is often exceeded at pristine locations in Alberta due to natural ozone generating processes. The 24-hour guideline for ozone is currently under review by a federal-provincial committee.

Small upward trends in ozone concentrations are evident from data collected at the Edmonton Central and Calgary Central monitoring stations. These upward trends are related to lower concentrations of oxides of nitrogen.

Nitrogen Dioxide

The 1-hour, 24-hour and annual guidelines for nitrogen dioxide were not exceeded at any Alberta monitoring stations in 1996. Annual average nitrogen dioxide and total oxides of nitrogen values show a significant downward trend at the Edmonton and Calgary Central monitoring stations.

Sulphur Dioxide

The 1-hour and 24-hour guidelines for sulphur dioxide were not exceeded at any of the monitoring stations in 1996. Annual average sulphur dioxide values are too low to resolve a significant trend.

Hydrogen Sulphide

The 1-hour guideline for hydrogen sulphide was exceeded at the Edmonton East (8 hours) and Fort MacKay (1 hour) monitoring stations. The 24-hour guideline was exceeded at the Edmonton East (1 day), Calgary East (1 day), and Fort Saskatchewan (1 day) stations. Exceedances of the hydrogen sulphide guidelines in East Edmonton were due to fugitive emissions from local industrial sources. The sewage treatment plant was the major cause of hydrogen sulphide exceedances at the Calgary East station.

Total Hydrocarbons

The highest hydrocarbon concentrations were generally reported at the Edmonton East monitoring station in 1996. A maximum hourly value of 18.3 ppm was recorded in March. Relatively high hourly values in East Edmonton were likely related to fugitive emissions from petroleum transport vehicles and petroleum storage tanks. Based on annual average values, a long-term downward trend in total hydrocarbons is evident at the Edmonton Northwest station. A slight upward trend in total hydrocarbons is indicated at the Calgary Northwest, Calgary East, Fort Saskatchewan and Fort McMurray monitoring stations.

Carbon Dioxide

Average concentrations of carbon dioxide at the Calgary Central and Springbank Airport stations in 1996 were 392 and 378 ppm, respectively. (Carbon Dioxide was monitored from January to June 1996 at the Springbank station.) The major source of carbon dioxide in downtown Calgary is fossil fuel combustion. Typical carbon dioxide values at pristine locations are about 345 ppm.

Ammonia

Ammonia concentrations were very low at the Fort Saskatchewan station in 1996. Concentrations were below the detection limit of the monitoring instrument close to 99% of the time. The overall maximum ammonia concentration was 0.5 ppm (25% of the 1-hour guideline).

Inhalable Particulates

In 1996, inhalable particulates were monitored continuously at the Edmonton Northwest and Calgary Central monitoring stations. The annual average inhalable particulate concentrations at these stations were 15.9 and 13.1 μg/m^3, respectively. The maximum 1-hour concentrations at these two stations were 302 and 169 μg/m^3, respectively. Major sources of inhalable particulates include vehicle exhaust emissions, residual sand and dust from winter road sanding and industrial emissions.

Total Suspended Particulates

The 24-hour guideline for total suspended particulates was exceeded at the Edmonton Northwest, Edmonton East, Calgary Central, Calgary East and Fort Saskatchewan stations in 1996. The highest number of exceedances was recorded at the Calgary East station (18 times). The annual average guideline of 60 μg/m^3 was also exceeded at the Calgary East station. The major sources of suspended particulates are vehicle exhaust, traffic movement on sanded streets and industrial emissions. A significant downward trend in suspended particulate loadings is evident at the Edmonton Central, Edmonton Northwest, Calgary Central, Calgary Northwest and Fort Saskatchewan monitoring stations.

Polycyclic Aromatic Hydrocarbons (PAHs)

In 1996, Alberta Environmental Protection began monitoring for a number of different PAHs: chrysene, benzo (b,k) fluoranthene, benzo (e) pyrene, benzo (a) anthracene, indeno (1,2,3-c,d) pyrene, dibenzo (a,h) anthracene and benzo (g,h,i) perylene. Benzo (a) pyrene has been monitored since 1982 at most stations. The highest PAH concentrations were recorded at monitoring stations that are influenced by the transport of vehicle emissions to the monitoring site (Edmonton Northwest, Edmonton Central, Calgary Central, and Calgary East stations). A significant dip in benzo(a)pyrene concentrations is evident in 1991 and 1992 at most urban monitoring stations. Based on data since 1982, a small upward trend in benzo(a)pyrene is evident at the Edmonton Northwest and Fort Saskatchewan stations.

Sulphate and Nitrates

The highest annual average sulphate values were reported at the Edmonton East, Calgary East and Fort Saskatchewan monitoring stations. Annual average nitrate concentrations were the highest at the Edmonton East and Calgary East stations. Relatively high sulphate and nitrate loadings were also recorded at other urban stations located in Edmonton and Calgary. Sulphate and nitrate loadings were higher at all Alberta stations from 1993 to 1996 compared to values measured from 1985 to 1987.

Total Sulphation

Exceedances of the guideline for total sulphation did not occur at either the Fort McMurray or the Raven Brood static monitoring networks in 1996. The annual average concentrations were 0.042 and 0.018 mg/day/100cm^2 at these two locations, respectively. Based on data from 1982 to 1996, a trend in total sulphation is not apparent.

Static Hydrogen Sulphide

The guideline for static hydrogen sulphide was not exceeded at the Fort McMurray network in 1996. Static hydrogen sulphide was not monitored at any other locations in 1996. Based on data from 1982 to 1996, a significant trend in static hydrogen sulphide is not apparent from data collected at the Fort McMurray network.

Precipitation pH

As with previous years, the most acidic (lowest pH) precipitation in 1996 was recorded at the Fort McMurray precipitation monitoring station, with an annual average pH value of 4.9. The highest pH value recorded was 5.6 at the Calgary precipitation monitoring station. The pH of precipitation in pristine areas ranges from 5.0 to 5.6.

Ions in Precipitation

The highest sulphate and nitrate deposition rates were recorded at the Calgary precipitation station in 1996. Calcium and ammonium concentrations in precipitation were also highest at the Calgary station. Chloride and phosphate wet deposition rates were relatively low at all monitoring stations. Wet deposition rates of sodium, magnesium and potassium were below 1.0 kg/ha/yr at all precipitation quality stations.

Effective Acidity of Precipitation

Effective acidity is an approach that has been developed to estimate the amount of acidity in the soil due to physical, chemical and biological processes which occur as a result of acid deposition. In 1996, the highest annual effective acidity deposition rate occurred at Calgary (0.08 kg(of H^+)/ha/yr). The minimum value calculated was at Suffield (0.03 kg(of H^+)/ha/yr).

Potential Acid Input of Precipitation

Potential acid input is described as the sum of base cation deposition (calcium, magnesium, and potassium) subtracted from the sum of the total sulphur and nitrogen deposition. This equation results in the total acid input into the ecosystem. A maximum annual potential acid input deposition rate of 0.13 kg(of H^+)/ha/yr was measured at Red Deer. The lowest annual potential acid input deposition rate occurred at Suffield (0.05 kg(of H^+)/ha/yr).

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ACKNOWLEDGEMENTS

The report that follows details air quality activities that were conducted by Alberta Environmental Protection in the province of Alberta during 1996. A great deal of technical expertise is necessary to collect high quality data from such an extensive monitoring program. The dedicated individuals who established and maintained this comprehensive monitoring program are accredited with this accomplishment.

J. Torneby, D. Kupina, D. Bensler, J. Ross, E. Boyko and M. Eliuk operated and maintained the continuous, intermittent and static monitoring networks in 1996. E. Boyko was responsible for maintaining the precipitation quality monitoring network. H. Benders and G. Bayard are acknowledged for the operation of the mobile air quality monitoring program. The Alberta Environmental Centre (currently operated by the Alberta Research Council) in Vegreville analyzed samples from the intermittent, static and precipitation quality monitoring networks.

LIST OF ABBREVIATIONS

IQUA	Index of the Quality of the Air
NH_3	ammonia
CO	carbon monoxide
CO_2	carbon dioxide
H_2S	hydrogen sulphide
NO_2	nitrogen dioxide
NO	nitric oxide
NO_X	oxides of nitrogen
N_2O	nitrous oxide
O_3	ozone
PM_{10}	inhalable particulates
SO_2	sulphur dioxide
THC	total hydrocarbons
TSP	total suspended particulates
BaP	benzo(a)pyrene
PAHs	polycyclic aromatic hydrocarbons
VOCs	volatile organic compounds
NAPS	National Air Pollution Surveillance
SSI	size selective inlet

UNITS OF MEASUREMENT

ppm	parts per million by volume
ppb	parts per billion by volume
$\mu g/m^3$	micrograms per cubic meter
ng/m^3	nanograms per cubic meter
kg/ha/yr	kilograms per hectare per year
kg (of H^+)/ha/yr	kilograms per hectare per year of hydrogen ion equivalent
$mg/day/100^2$	milligrams per day per 100 square centimetres
km/hr	kilometers per hour
COH units	coefficient of haze units measured as the reduction of light transmission per 1000 linear feet of air sample

1. INTRODUCTION

Air quality issues such as urban air quality, photochemical smog, acidic deposition and global warming have received increased attention over the past several years. Alberta Environmental Protection recognizes that the quality of the air and its impact on human and ecological health is a primary concern to many Albertans. The Air Issues and Monitoring Branch of Alberta Environmental Protection operates a comprehensive air quality monitoring program consisting of continuous, intermittent, static, and precipitation quality monitoring networks, as well as special monitoring surveys. The overall objective of the monitoring program is to: ***determine the status, changes and trends in selected measures of air quality in the province***. Specific objectives of this air quality monitoring program are to:

- *provide data for the assessment of existing air quality relative to air quality guidelines;*
- *inform the public on the status of air quality;*
- *monitor air quality representative of urban environments;*
- *report long-term trends in air quality; and*
- *undertake monitoring in special problem areas.*

This report presents an interpretive analysis of air quality data collected by this program in 1996. When exceedances of air quality guidelines occur, an attempt is made to relate the exceedances to wind direction so that the source or sources of the pollutant may be identified. Long-term trends of pollutant concentrations are also presented and an explanation of these trends is included.

Air quality instrumentation and data are subject to a stringent quality control and quality assurance program. Instrument calibration and data collection procedures are detailed in the Alberta Environmental Protection Air Monitoring Directive (Alberta Environment, 1989). After the data has been collected, quality control is conducted by a technologist to ensure that the data presented in monthly, quarterly and annual reports are certified as being correct. If the quality of the data is questionable, it is deleted from the database and not included in monthly, quarterly or annual reports.

Detailed analyses of data collected by continuous, intermittent, static and precipitation quality monitoring networks that are operated by Alberta Environmental Protection are presented in this report. The data used to generate this report are contained in a separate document entitled "Air Quality Monitoring in Alberta: 1996 Data Report." The results of mobile and special monitoring surveys are summarized in this report.

2. AIR QUALITY MONITORING NETWORKS

2.1 CONTINUOUS MONITORING NETWORK

Air pollutants are monitored on a continuous basis at eleven locations in Alberta. Three continuous monitoring stations are located in both Calgary and Edmonton. Additional stations are located in Fort Saskatchewan, Fort McMurray, Fort MacKay, Springbank (near Calgary) and Royal Park (near Vegreville). Each continuous monitoring unit is equipped to monitor air quality parameters on an hourly basis. These parameters are listed in Table 2.1. The locations of continuous monitoring stations are presented in Figure 2-1 and Table 2.2.

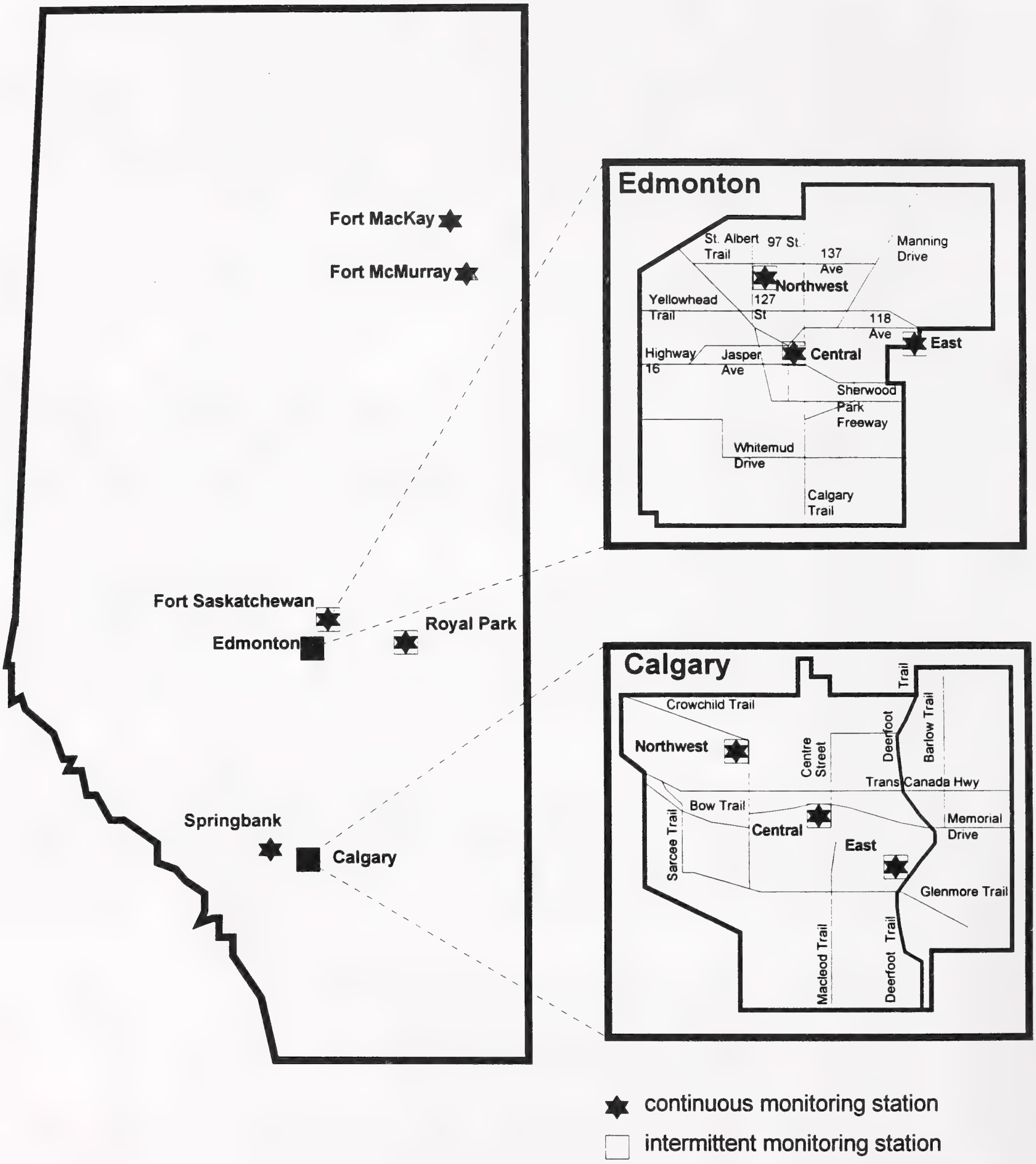


Figure 2-1 Location of continuous and intermittent air quality monitoring stations.

Table 2.1 Pollutants monitored at continuous air quality monitoring stations.

Monitoring Station	Parameter										
	NH_3	CO	CO_2	COH	H_2S	NO_X [a]	O_3	PM_{10} [b]	SO_2	THC	Wind
Edmonton Central		X		X		X	X			X	
Edmonton Northwest		X		X		X	X	X		X	X
Edmonton East		X		X	X	X	X		X	X	X
Calgary Downtown		X	X	X		X	X			X	
Calgary Residential		X		X		X	X			X	X
Calgary Industrial		X		X	X	X	X		X	X	X
Fort Saskatchewan	X	X		X	X	X	X		X	X	X
Fort McMurray		X		X	X	X	X		X	X	X
Fort MacKay					X				X	X	X
Springbank			X				X				X
Royal Park						X	X				X

[a] includes NO_2 and NO

[b] inhalable particulate matter less than 10 micrometres in diameter

Table 2.2 Location of continuous monitoring stations.

Station Name	Station Location
Edmonton Central (Downtown) Monitoring Unit (EDMU)	10255 - 104 St.
Edmonton Northwest (Residential) Monitoring Unit (ERMU)	13335 - 127 St.
Edmonton East (Industrial) Monitoring Unit (EIMU)	105 Ave. and 17 St.
Calgary Central (Downtown) Monitoring Unit (CDMU)	611 - 4 St. SW
Calgary Northwest (Residential) Monitoring Unit (CRMU)	39 St. and 29 Ave. NW
Calgary East (Industrial) Monitoring Unit (CIMU)	49 Ave. and 15 St. SE
Fort Saskatchewan Monitoring Unit (FTSK)	9209A - 96 Ave.
Fort McMurray Monitoring Unit (FMMU)	Franklin Ave. at old waterpump house site
Fort MacKay Monitoring Unit (FRMU)	100 m west of the Fort MacKay Band Council Administration Office
Springbank (SPBK)	20 km west-northwest of downtown Calgary at the Springbank Airport
Royal Park (RLPK)	10 km northwest of Vegreville

The Edmonton and Calgary monitoring stations are designated according to their general location in the downtown (Edmonton Central and Calgary Central), northwest (Edmonton Northwest and Calgary Northwest) and east (Edmonton East and Calgary East) sections of the cities. All Edmonton and Calgary air quality stations are equipped to monitor ambient concentrations of carbon monoxide (CO), dust and smoke (in COH units), oxides of nitrogen (including NO, NO_2 and NO_X), ozone (O_3), and total hydrocarbons (THC). In addition, the Edmonton East and Calgary East stations monitor sulphur dioxide (SO_2) and hydrogen sulphide (H_2S). With the exception of the Edmonton and Calgary Central locations, all stations monitor wind speed and direction. Carbon dioxide (CO_2) monitoring was added at the Calgary Downtown monitoring location in March of 1991. Continuous monitoring of inhalable particulates was initiated at the Edmonton Northwest station in November of 1993 and at the Calgary Central station in June of 1995.

The continuous monitoring stations in Fort Saskatchewan and Fort McMurray monitor for the same pollutants as the Edmonton East monitoring station (i.e., CO, COH, H_2S, NO_X, NO, NO_2, O_3, SO_2 and THC) with the addition of ammonia (NH_3) at the Fort Saskatchewan station. Only SO_2, H_2S and THC are monitored at the Fort MacKay monitoring station. Wind direction and speed are also monitored at these small urban stations.

The Springbank and Royal Park monitoring stations were set up to monitor rural air quality which is not influenced substantially by a major source. The Springbank monitoring station is located 20 km west-northwest of downtown Calgary and, depending on wind direction, will monitor air quality upwind of Calgary. Air quality parameters monitored at the Springbank station in 1996 included CO_2, O_3, wind speed and wind direction. The Royal Park monitoring station, located about 10 km northwest of Vegreville, Alberta, was established as a prototype acid deposition monitoring station. O_3, NO_X, NO, NO_2, dry and wet acid deposition, and numerous meteorological parameters were monitored at the Royal Park station in 1996. O_3, NO_X, NO, NO_2 and wind data from Royal Park will also be presented in this report. Acid deposition data from this location is presented in other Alberta Environmental Protection reports (Reuter and Guan, 1995; Bates, 1996).

2.2 INTERMITTENT MONITORING NETWORK

Suspended particulates are monitored, as a 24-hour accumulated loading, at Edmonton and Calgary continuous monitoring locations as well as at Fort Saskatchewan and Royal Park stations (refer to Figure 2-1). Suspended particulate samples are collected by high-volume samplers and subsequently submitted for laboratory analysis to quantify loadings of total suspended particulates (TSP), polycyclic aromatic hydrocarbons, sulphates and nitrates. Suspended particulates are monitored on every sixth day in accordance with the National Air Pollution Surveillance (NAPS) schedule. Parameters monitored at intermittent stations are indicated in Table 2.3.

In addition to high-volume samplers, Alberta Environmental Protection also operates two dichotomous samplers and two size selective inlet (SSI) samplers to monitor total suspended particulates in the province. The dichotomous samplers are located at the Edmonton Central and Calgary Central monitoring stations. One SSI sampler is also located at the Edmonton Central monitoring station, while the other is situated at the Edmonton Northwest monitoring station. A dichotomous sampler separates particulates into two size fractions; fine (less than 2.5 micrometres in diameter) and coarse (2.5 to 10 micrometres in diameter) (a human hair is about 100 micrometres in diameter). A SSI sampler collects all particulates with a diameter less than 10 micrometres. The monitoring frequency of the dichotomous and SSI instruments conforms to the NAPS network schedule (i.e., every sixth day). These monitoring programs are conducted in cooperation with Environment Canada.

Table 2.3 **Pollutants monitored at intermittent air quality monitoring stations.**

Monitoring Station	Parameter					
	TSP	PAHs	Sulphate	Nitrate	Inhalable Particles [a]	VOCs [b]
Edmonton Central	X	X	X	X	X	X
Edmonton Northwest	X	X	X	X	X	
Edmonton East	X	X	X	X		X
Calgary Central	X	X	X	X	X	X
Calgary Northwest	X	X	X	X		
Calgary East	X	X	X	X		
Fort Saskatchewan	X	X	X	X		
Royal Park	X	X	X	X		

a particles less than 10 micrometres in diameter (PM_{10})

b includes 150 volatile organic compounds

Volatile organic compounds (VOCs) are monitored, as a 24-hour integrated concentration, at the Edmonton Central, Edmonton East and Calgary Central stations every sixth day in accordance with the NAPS schedule. Analysis for 150 VOCs and interpretation of VOC data is undertaken by Environment Canada.

2.3 STATIC MONITORING NETWORK

Static monitoring is the measurement of total accumulations of pollutant loadings over a one-month time period. After June 30, 1995 the static monitoring program was reduced from 31 static monitoring networks to 2 networks (Fort McMurray and Raven Brood). Air quality parameters and the number of stations per network for monthly networks are listed in Tables 2.4. Figure 2-2 shows static monitoring network locations.

Alberta Environmental Protection is currently exploring alternative methods to measure air parameter concentrations using static methods (Alberta Research Council, 1995). Static monitoring techniques for chemicals such as oxides of nitrogen, ozone, sulphur dioxide and volatile organic compounds are currently being investigated. These alternative static monitoring methods may provide a cost effective solution for monitoring air quality at locations where continuous monitoring is not practical. The government static monitoring program is currently being modified based on the evaluation of new static monitoring techniques.

Table 2.4 **Parameter and number of stations for monthly static monitoring networks.**

Network Location	Parameter and Number of Stations	
	Total Sulphation	Hydrogen Sulphide
Fort McMurray	6	6
Raven Brood	1	*

*Hydrogen sulphide was not measured at the Raven Brood station.

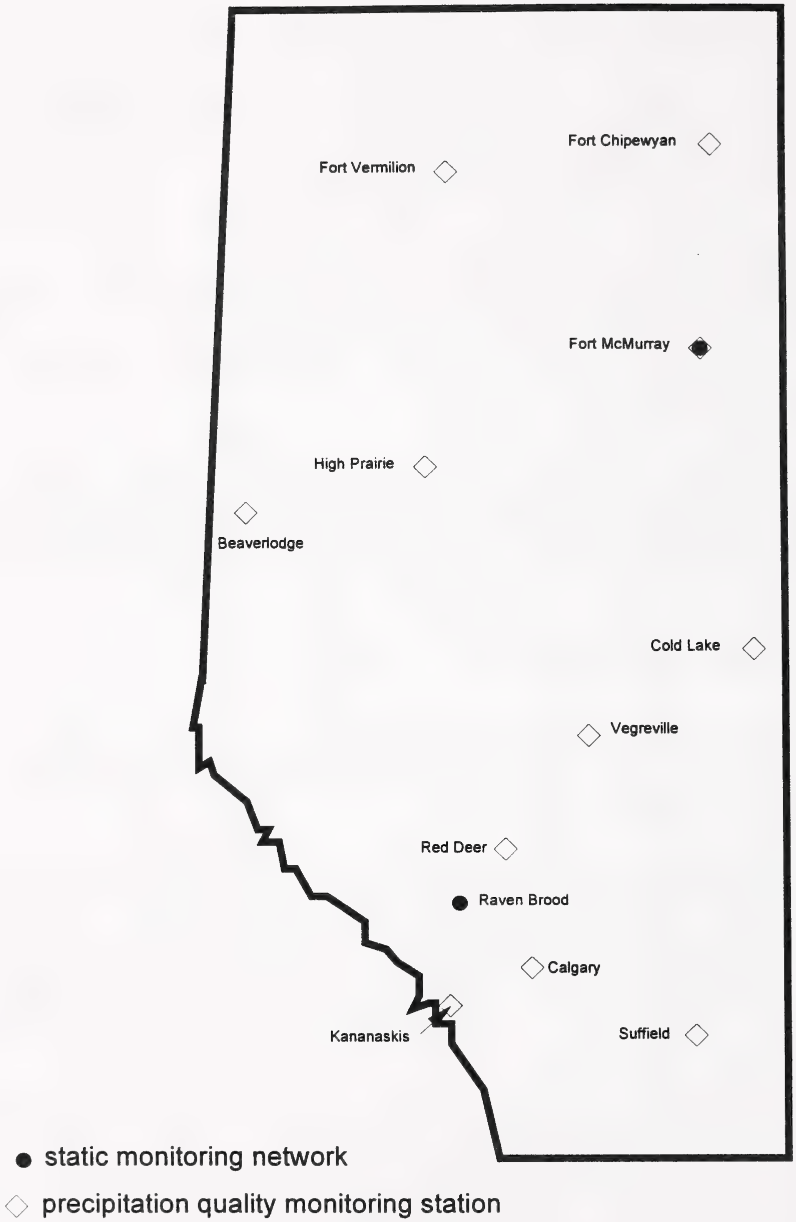


Figure 2-2 **Location of static monitoring networks and precipitation quality monitoring stations.**

2.4 SPECIAL MONITORING SURVEYS

Special air quality monitoring surveys are conducted by Alberta Environmental Protection to:

- obtain province-wide air quality data;
- explore potential sites for Alberta's permanent monitoring network;
- identify any potential problem areas; and
- respond to air quality concerns from the community.

Many of the these air quality surveys are initiated on the basis of public concerns or requests from municipal officials. To conduct special surveys, Alberta Environmental Protection uses continuous, intermittent and passive monitoring techniques.

Most special air quality surveys involve collecting air quality data on a continuous basis using the Mobile Air Monitoring Laboratory (MAML). The MAML is a 27-foot (8.2 m) vehicle that has been specially designed and equipped to measure the air quality (Figure 2-3). It houses a variety of instruments that sample the air at specified time or distance intervals, and analyze the samples quickly and reliably. The MAML is equipped with:

- a dual computer system with a custom program to control the measurement and storage of air samples from each analyzer;
- a GPS (Global Positioning System) that will identify the location of the unit as it moves around Alberta;
- an exhaust scrubbing system that filters emissions for a cleaner-running vehicle; and
- two on-board generators that are also equipped with exhaust scrubbers.

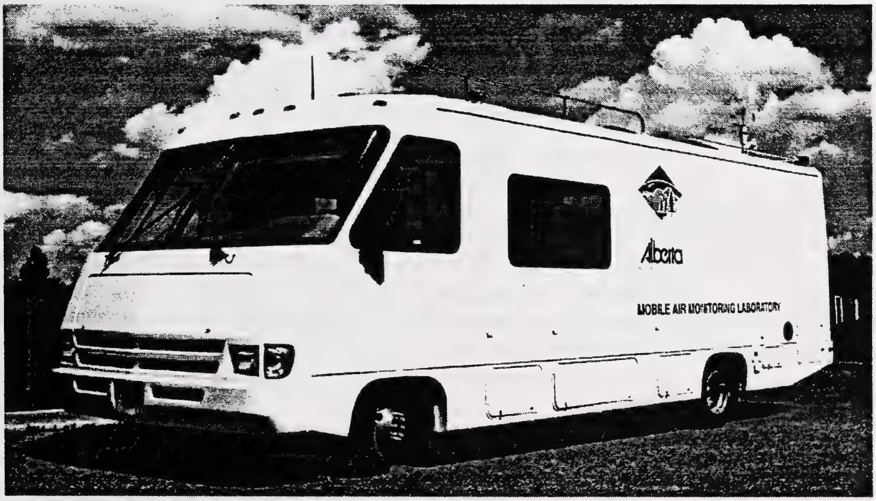


Figure 2.3 **Alberta Environmental Protection's Mobile Air Monitoring Laboratory (MAML)**

The MAML measures many different atmospheric substances (carbon monoxide, hydrogen sulphide, total reduced sulphur, sulphur dioxide, oxides of nitrogen, ozone, hydrocarbons and particulates) as well as wind speed, wind direction, temperature, and relative humidity. Alberta Environmental Protection also has access to a second mobile unit that is capable of monitoring ozone, oxides of nitrogen, total hydrocarbons, hydrogen sulphide and sulphur dioxide. This second unit is used in surveys where a large area is covered or when coincidental air quality readings are required at two locations.

Intermittent and passive monitoring techniques are also used in special air quality monitoring surveys to obtain air parameter concentrations that are currently beyond the capability of the MAML. For example, intermittent techniques may be required to conduct speciation of volatile organic compounds, polycyclic aromatic hydrocarbons or sulphur compounds. Passive techniques can be used to obtain longer term concentrations of compounds such as sulphur dioxide, nitrogen dioxide, ozone, hydrogen sulphide or total sulphation.

Special air quality monitoring surveys were conducted in Red Deer, Strathcona County, the Sturgeon Regional Landfill area and the Swans Hills area in 1996. These surveys are summarized below.

➢ *Red Deer*

A special air quality survey was conducted in the City of Red Deer on February 26, 1996 in order to measure air quality parameter concentrations on a cold winter day. The original study was initiated at the request of the Environmental Advisory Committee of the City of Red Deer. The objective of the original monitoring survey was to determine air pollution levels in Red Deer representative of specific sectors of the city for the spring, summer, fall and winter seasons. Air quality was measured at five different locations in the City of Red Deer for approximately one hour at each location. The air parameters monitored were carbon monoxide, ozone, total hydrocarbons and oxides of nitrogen. The major findings of the survey are:

- Air quality guidelines were not exceeded for any of the air quality parameters monitored on February 26.

- Air quality levels observed on February 26, 1996 were similar to the those of March 2, 1995 in Red Deer.

➢ *Strathcona County*

Alberta Environmental Protection conducted an air quality monitoring program in Strathcona County in the summer and fall of 1996. The objectives of this program were to: (1) determine air quality parameter concentrations in the community of Sherwood Park relative to air quality guidelines and to other small urban locations in the province; and (2) determine the concentrations of specific chemical species in the Strathcona industrial area and at upwind and downwind locations from the industrial area. The program began in the summer of 1996 and when completed, the results the results will be detailed in a separate report.

Air quality was measured using the MAML at five locations in Sherwood Park and using the second mobile unit at seven locations in the Strathcona industrial area. Air quality parameters monitored in Sherwood Park using the MAML included carbon monoxide, ozone, hydrocarbons, oxides of nitrogen, hydrogen sulphide and sulphur dioxide. The second mobile monitoring unit was used to monitor ozone, oxides of nitrogen, total hydrocarbons, sulphur dioxide and hydrogen sulphide in the Strathcona industrial area. Additional chemicals monitored using integrated techniques (volatile organic compounds and polycyclic aromatic hydrocarbons collected as a 24-hour sample) were also collected in Sherwood Park and the Strathcona industrial area.

The following were the results of the monitoring activities that took place in 1996:

- Concentrations of all air quality parameters monitored in Strathcona County in the summer and fall were below the air quality guidelines.
- Concentrations of pollutants emitted by vehicles (CO, NO_2, NO and THC) were highest at sites located in western Sherwood Park and near major traffic arteries in the Strathcona industrial area. Higher levels at these locations are likely due to the influence of vehicle exhaust from major traffic arteries (e.g. Baseline Road, Wye Road, Yellowhead Trail and 17th Street).
- Concentrations of sulphur compounds (H_2S and SO_2) were general very low in Sherwood Park and the Strathcona industrial area on all survey days. However, an elevated 1-hour average SO_2 concentration of 0.073 ppm (the 1-hour guideline is 0.170 ppm) was recorded on the Highway 14X off ramp to Baseline Road in the afternoon of October 28.

➢ *Sturgeon Regional Landfill*

A special air quality monitoring survey was conducted in the vicinity of the Sturgeon Regional Landfill on July 2 and July 12, 1996. The objective of the survey was to address concerns expressed by local residents regarding air quality near the landfill site. Air quality parameters were monitored using the MAML and charcoal tube samplers (for volatile organic compounds). The results of the survey indicated that:

- Air quality guidelines were not exceeded in the vicinity of the landfill site; and
- Concentrations of almost all volatile organic compounds were below the laboratory detection limit.

➢ *Swan Hills*

Alberta Environmental Protection conducted an air quality monitoring survey in the Swan Hills area of northwestern Alberta on September 17, 18 and 19, 1996. The objective of this program was to determine air quality parameter concentrations in the Swan Hills region relative to Alberta's air quality guidelines and to other locations in the province. The program began in the fall of 1996 and is expected to be completed by the spring, 1998. Air quality was measured using two mobile monitoring units in the communities of Fort Assiniboine, Swan Hills, Kinuso, Grouard, Joussard, Hondo and Valleyview. Monitoring was also conducted while in transit between these communities. Air quality parameters monitored at these locations included carbon monoxide, ozone, hydrocarbons, oxides of nitrogen, hydrogen sulphide and sulphur dioxide.

Concentrations of all air quality parameters monitored in the Swan Hills area were below the air quality guidelines. Maximum 1-hour average concentrations were:

- 6% of the 1-hour guideline for carbon monoxide;
- 40% of the 1-hour guideline for ozone;
- 10% of the 1-hour guideline for nitrogen dioxide;
- 40% of the 1-hour guideline for hydrogen sulphide; and
- 4% of the 1-hour guideline for sulphur dioxide.

2.5 PRECIPITATION QUALITY MONITORING NETWORK

Precipitation chemistry was monitored, on a weekly basis, at 11 locations in the province by Alberta Environmental Protection in 1996. The locations of precipitation quality monitoring stations are indicated in Figure 2-2.

In September of 1992, the sampling interval for precipitation at all locations was increased to from monthly to weekly. Recent studies have indicated that sampling of precipitation on a monthly basis does not adequately reflect precipitation chemical properties (Lau, 1990; Peake, 1992). A comparison of daily versus monthly samples shows that pH values and concentrations of other ions are consistently lower in daily samples. This is due to chemical reactions which take place while the sample remains in the field over the period of a month. Because of these discrepancies, Alberta Environmental Protection changed the frequency of precipitation monitoring from monthly to weekly. Daily sampling is not practical because of the increased load on the station operators and the cost of laboratory analysis.

Laboratory analysis is conducted on precipitation samples to obtain pH, strong acidity, total acidity, specific conductance; and concentrations of sulphate, nitrate, ammonia, chloride, phosphate, sodium, potassium, calcium and magnesium.

3. FACTORS AFFECTING AIR POLLUTANT DISPERSION

The quality of the air is dependent on the rate that pollutants are emitted into the atmosphere and the ability of the atmosphere to disperse the pollutants. Air pollutant transport and dispersion are influenced by wind direction and speed, the temperature structure of the atmosphere, turbulence and the changes in these elements induced by local topography.

3.1 WIND

Wind is the movement of the air caused by changes of pressure and temperature in the atmosphere. Wind direction will determine the trajectory, or path, of air pollutants from their source to any receptor. Wind speed and the distance from the source will determine the time it will take air pollutants to travel from source to receptor.

At high wind speeds, the air will experience more mechanical turbulence and pollutants released near ground-level will disperse more rapidly. However, air pollutants emitted by elevated stack sources may be more rapidly transported to the ground during high wind speeds and can actually lead to higher ground-level pollutant concentrations. At low wind speeds, pollutants emitted from sources near ground-level, such as vehicle exhaust, will disperse at a slower rate.

3.2 TEMPERATURE STRUCTURE

The rate of change of temperature with altitude has a substantial effect on mixing of air pollutants. The diurnal (daily) and seasonal solar cycles will essentially control the temperature profile of the lower atmosphere.

During the day, the temperature in the lower atmosphere typically decreases with height, the rate depending on the amount of energy received from the sun. As evening approaches, solar heating decreases and the earth's surface experiences a net heat loss to the atmosphere. As the ground cools, the lower levels of the atmosphere will also cool. The vertical temperature profile of the atmosphere is now the reverse of the daytime situation. This increasing temperature with height is referred to as a temperature inversion. Temperature inversions will generally last longer during the winter and fall than in the spring and summer seasons. In winter, temperature inversions can last all day. The combination of a strong temperature inversion and light winds may lead to a layer of cold, stagnant air near the ground. Pollutants emitted from low-level sources, such as vehicles, are trapped in this layer of air. A persistent temperature inversion over a long period of time may lead to increased concentrations of air pollutants in the lower atmosphere from low level sources.

The region of air that extends from the earth's surface to the base of the temperature inversion is referred to as the mixing layer. This layer of air is relatively well-mixed due to heating from the sun and from human sources. The depth of the mixing layer defines the volume of air in which air pollutants can be mixed. The lower the depth of the mixing layer, the less volume that is available to disperse air pollutants. A persistent lack of a mixing layer or shallow mixing depth may lead to episodes of high pollution concentrations. The mixing layer is especially important in urban locations where large quantities of pollutants are released near ground-level.

3.3 TURBULENCE

Turbulence in the atmosphere describes the random motion of a parcel of air at a specific point in space. This random motion in the atmosphere is a primary factor in determining the dispersion of air pollutants. Atmospheric turbulence is governed by mechanical processes such as wind and topography, and by thermal forces such as solar heating.

Under high wind speeds, the frictional force of air movement over the ground will create mechanical turbulence. Mechanical turbulence is the dominant mechanism for atmospheric mixing on windy days and at night.

When the earth's surface is heated by the sun, pockets of warm air will form near the ground. This less dense, warm air will rise from ground-level to be replaced by cooler air. The cooler air is, in turn, heated and thus ascends creating thermal or convective turbulence. This vertical motion in the atmosphere becomes more intense as solar heating increases. Convective turbulence causes vigorous atmospheric mixing which allows air pollutants to disperse rapidly. During daylight hours, when winds are light to moderate, atmospheric overturning, or convection, is the dominant mechanism for pollutant dispersion.

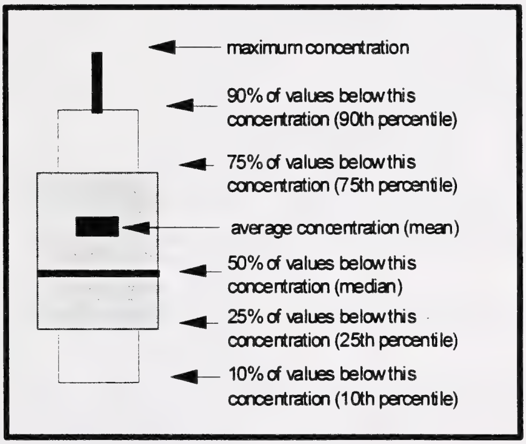
3.4 TOPOGRAPHY

The structure and orientation of terrain features will often influence and even control air motion and mechanical turbulence in the lower atmosphere. Small hills and trees may alter wind speed and direction while also enhancing mechanical turbulence. Larger terrain features such a mountains, hills and valleys may be a governing factor in the control of wind speed and wind direction. For example, wind may be diverted around large hills and mountains and channelled through valleys. Important diurnal variations of wind may also be caused by terrain features. A common cause for air pollution episodes in a valley which contains numerous pollutant sources, is the occurrence of a persistent temperature inversions.

4. CONTINUOUS MONITORING RESULTS

Data analysis has been conducted on all parameters which are monitored continuously by Alberta Environmental Protection. A summary of the results of individual parameters collected by the continuous air quality network is preceded by a discussion of the Index of the Quality of the Air.

Concentrations of individual pollutants are summarized, on a monthly basis, in diagrams referred to as percentile diagrams or frequency distribution diagrams. An explanation of these diagrams is presented below:


maximum concentration
90% of values below this concentration (90th percentile)
75% of values below this concentration (75th percentile)
average concentration (mean)
50% of values below this concentration (median)
25% of values below this concentration (25th percentile)
10% of values below this concentration (10th percentile)

Analysis of trends of continuously monitored parameters are presented when at least four years of historical data are available. Trend analysis was conducted through the application of Daniel's Trend Test (U.S. Environmental Protection Agency 1974; World Health Organization 1980). This is a non-parametric sign-rank test which ranks observations from lowest to highest and compares the rank to the chronological order of the observations. From this, a value of the Spearman Rank Correlation Coefficient may be obtained. A trend is considered significant if the probability of the trend being correct is 95% or greater; that is a 95% level of confidence has been established.

4.1 INDEX OF THE QUALITY OF THE AIR

The Index of the Quality of the Air (IQUA) is a system that has been developed to report ambient concentrations of specific pollutants in a manner that can be easily understood by the general public. The IQUA was developed by a federal-provincial committee in 1978 and adopted by Alberta Environmental Protection in December of 1979. In 1995, the dust and smoke component of the index was modified to better represent the inhalable particulate fraction (Environment Canada, 1996).

One way to describe the quality of the air is to report the concentrations of each pollutant. However, this can be confusing and make interpretation difficult because each pollutant has different potential effects at different concentrations. The IQUA relates the effects of different pollutants to one common scale.

The IQUA converts the measurements of five major pollutants (CO, dust and smoke, NO_2, O_3, and SO_2) to a single number and corresponding air quality description. An IQUA number of 1 to 25 indicates Good air quality; 26 to 50 is Fair air quality; 51 to 100 is Poor air quality; and a number greater than 100 indicates Very Poor air quality. For example, an index reading of 30 (Fair) for two individual pollutants indicates the same degree of environmental impact for each individual pollutant. The specific effects themselves, however, will vary according to the pollutant.

With the exception of dust and smoke, the air pollutant concentrations are linked to guidelines under Alberta's Environmental Protection and Enhancement Act and the National Air Quality Objectives. These guidelines and objectives consider the effects of different pollutants on human health, animals, vegetation, or general concerns such as odour and visibility. The IQUA rating categories are defined in Table 4.1.

In 1993, Alberta Environmental Protection increased the frequency of reporting of the IQUA from twice daily on week days to hourly, seven days a week. The IQUA is now available to the Alberta public and media 24 hours a day, seven days a week for Edmonton and Calgary. The IQUA telephone number is ***427-7273*** in Edmonton and ***250-2099*** in Calgary.

Table 4.1 Definition of IQUA rating categories.

IQUA rating	Frequency in Alberta	Effects
Good	almost all the time	Desirable range: no known harmful effects to soil, water, vegetation, animals, materials, visibility or human health. The long-term goal in Canada is for air quality to be in this range all the time.
Fair	occasional	Acceptable range: adequate protection against harmful effects to soil, water, vegetation, animals, materials, visibility and human health.
Poor	very seldom	Tolerable range: not all aspects of the environment are adequately protected from possible adverse effects. Long-term control action may be necessary, depending on the frequency, duration and circumstances of the readings.
Very Poor	very rare	Intolerable range: in this range, continued high readings could pose a risk to public health.

4.1.1 Results

The IQUA is calculated each hour and is summarized in monthly data reports for all Edmonton, Calgary, Fort Saskatchewan and Fort McMurray continuous air quality monitoring stations. A summary of the frequency of the IQUA categories and the contribution of each pollutant to the IQUA category is presented for each monitoring station in Figure 4-1. A monthly distribution of the IQUA category, and pollutants that contribute to the IQUA category are illustrated in Figures 4-2 and 4-3, respectively.

Good air quality was observed at least 94% of the time at all Alberta Environmental Protection monitoring stations on an annual basis in 1996. The frequency of Good air quality ratings ranged from 94.5% in Fort Saskatchewan to 99.9% at the Calgary Central station. Fair air quality ratings were most frequent at the Fort Saskatchewan station (5.5%) and at the Calgary Northwest station (2.8%). Air quality was in the Fair category less than 2% of the time at the remaining stations. Poor air quality was reported less than 0.05% of the time (4 hours) at all stations. Very Poor ratings were not observed at any monitoring stations in 1996.

The pollutants responsible for the IQUA ratings are largely dependent on the location of the air quality station relative to the source or sources. When the IQUA was Fair or Poor, dust and smoke or ozone were the dominant air pollutants. Dust and smoke influenced Fair and Poor air quality ratings at stations located near major traffic arteries in the fall and winter seasons (Edmonton and Calgary stations). Ozone was the dominant pollutant at all stations during the spring and summer. Nitrogen dioxide and carbon monoxide occasionally caused Fair or Poor air quality ratings at the Edmonton Northwest, Edmonton East, Calgary Central and Calgary East monitoring stations.

➢ *Edmonton*

The frequency of Good air quality ratings ranged from 98.6% of the time at the Edmonton East monitoring location to 99.7% of the time at the Edmonton Central monitoring station. Fair air quality ratings were measured most often at the Edmonton East station (1.4% of the time). The highest frequency of Fair air quality ratings were recorded in the summer months at all Edmonton stations. Poor air quality ratings were recorded for two hours at the Northwest station. This Poor air quality episode occurred on August 30 from 1 p.m. to 3 p.m. and was caused by elevated ozone levels during hot weather conditions. Winds were from the east-southeast direction prior to the episode. High ozone concentrations are likely caused by the combination of (1) ozone produced by natural sources; and (2) ozone produced from emissions of ozone precursors (oxides of nitrogen and volatile organic compounds) from automobiles and industry. Very poor air quality did not occur at any Edmonton monitoring stations in 1996.

➢ *Calgary*

Good air quality was measured from 97.0% of the time at the Calgary Northwest station to almost 99.9% of the time at the Calgary Central station. Fair air quality ratings were most frequent at the Northwest monitoring station (3.0% of the time). Fair air quality was reported 0.2% and 1.4% of the time at the Central and East stations, respectively. Two hours of Poor air quality were reported at the East station on January 9 (10 and 11 a.m.). This air quality episode was due to dust and smoke from vehicle exhaust emissions following the morning rush hour combined with stagnant weather conditions. Poor air quality was also recorded at the East station for one hour in the afternoon of December 4. This Poor air quality episode occurred at 2 p.m. and was caused by vehicle exhaust emissions combined with a strong temperature inversion and light winds. Poor or Very Poor air quality did not occur at any other Calgary monitoring stations.

➢ *Fort Saskatchewan and Fort McMurray*

Good and Fair air quality was reported 94.5% and 5.5% of the time, respectively, at the Fort Saskatchewan monitoring station. Poor air quality was measured 0.04% of the time (4 hours) at Fort Saskatchewan due to elevated ozone concentrations. These ozone episodes occurred for one hour each in the afternoon on August 9, 29, and for two hours in the afternoon on August 30 during hot weather conditions (temperatures greater than 25°C). Winds were from the west-southwest prior to the episodes on August 9 and 29, and from the southeast to south-southeast prior to the episode on August 30. These high ozone levels may have been caused by the combination of ozone generated by natural processes with the possible influence of ozone precursors (oxides of nitrogen and organic compounds) emitted in the Edmonton and Fort Saskatchewan area.

At the Fort McMurray station, Good air quality occurred over 99% of the time. Fair air quality was recorded the remainder of the time. Poor or Very Poor air quality readings were not recorded in Fort McMurray in 1996.

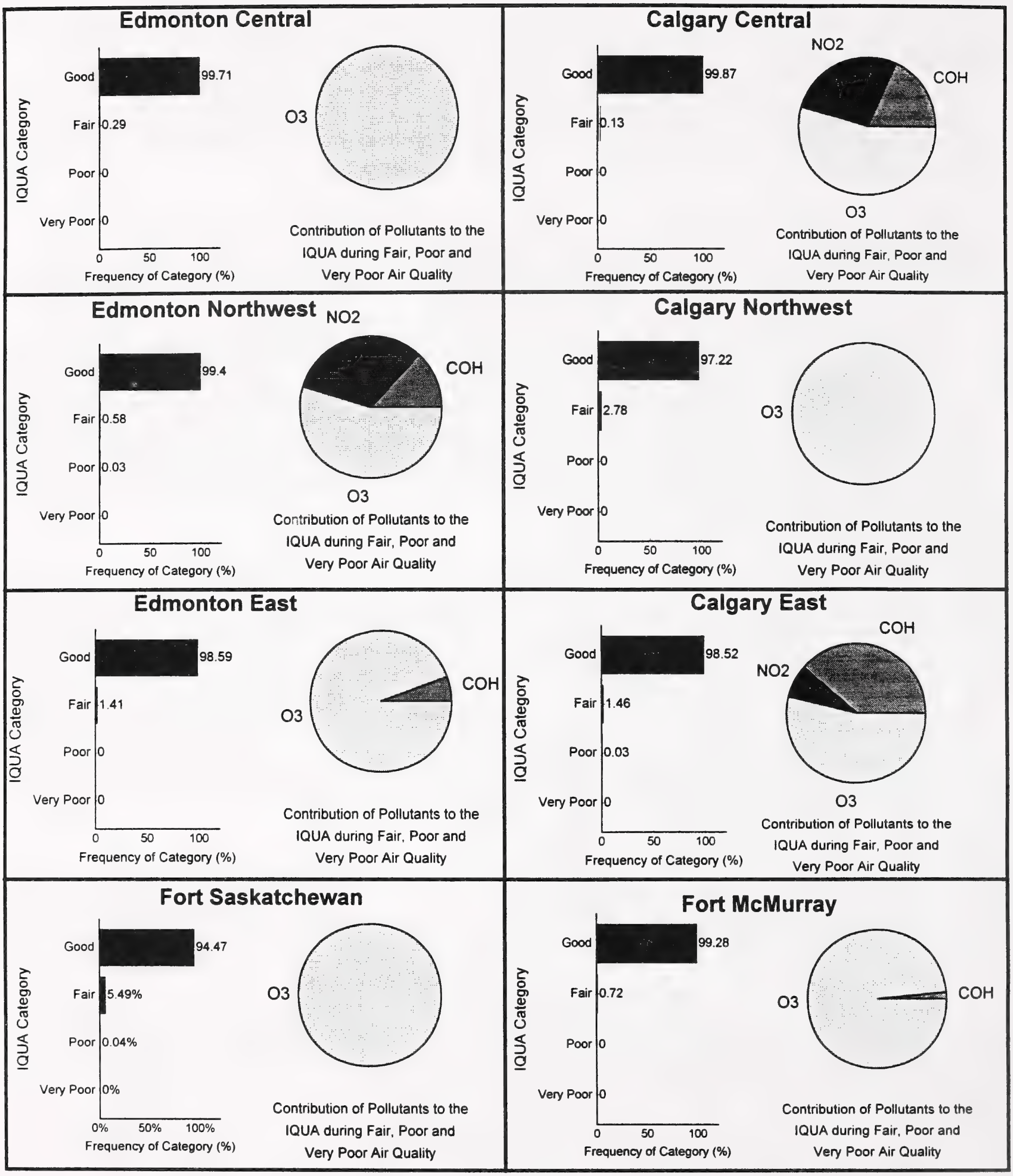


Figure 4-1 Annual frequency of the IQUA category and the pollutants that contributed to fair, poor, or very poor air quality in 1996.

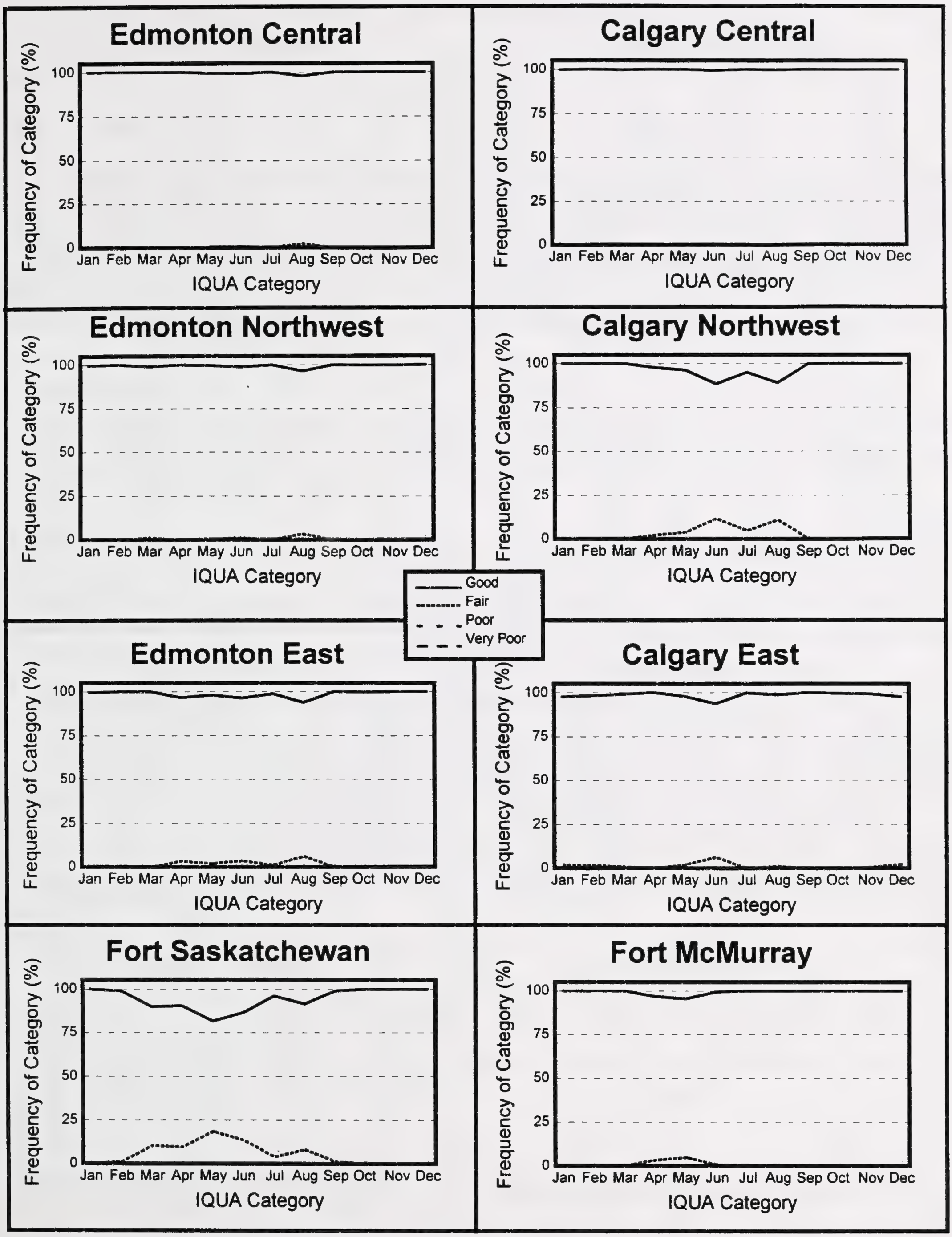


Figure 4-2 Monthly frequency distribution of the IQUA category.

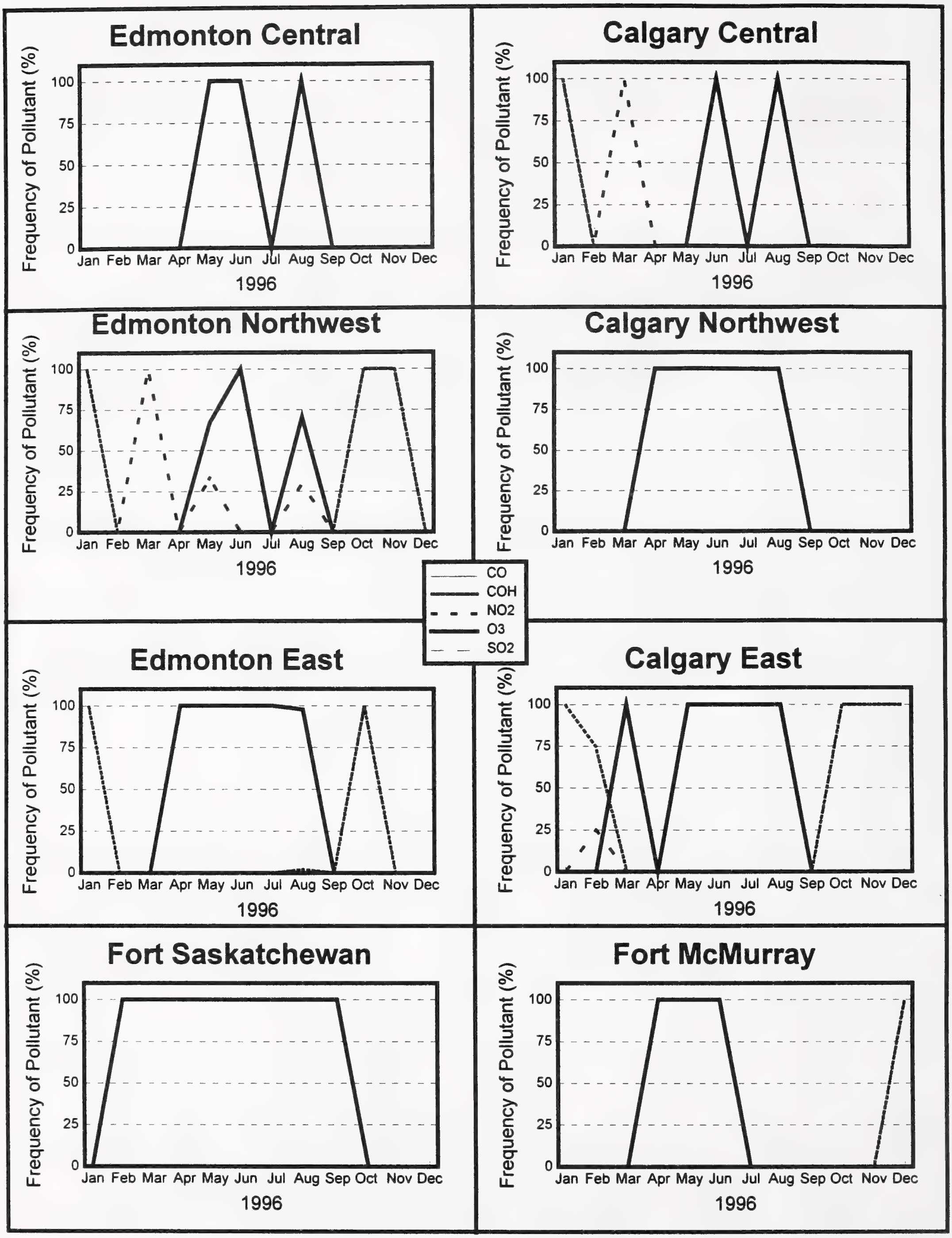


Figure 4-3 Monthly frequency distribution of pollutants contributing to Fair, Poor and Very Poor air quality.

4.2 WIND

4.2.1 *Results*

Wind speed and direction are routinely monitored at the 10-m level at the Edmonton Northwest, Edmonton East, Calgary Northwest, Calgary East, Fort Saskatchewan, Fort McMurray and Fort MacKay monitoring stations. In 1996, wind was also monitored at the Royal Park monitoring station (10 km northwest of Vegreville, Alberta) and at the Springbank Airport (20 km west-northwest of Calgary) from January to June. Wind direction frequency distributions for Edmonton and Calgary monitoring stations; Fort Saskatchewan, Fort McMurray and Fort MacKay monitoring stations; and Springbank and Royal Park monitoring stations are presented in Figures 4-4, 4-5 and 4-6, respectively.

➢ *Edmonton*

At the Edmonton Northwest station, the primary wind directions were west to north-northwest (29% of the time) and south (8% of the time). At the East monitoring station, the most common wind directions were southeast to south-southwest and west-northwest to north-northwest, occurring 37% and 22% of the time, respectively.

➢ *Calgary*

At the Northwest site, the winds predominantly had a west or west-northwest component (41% of the time). Winds from the southeast occurred about 8% of the time. At the Calgary East monitoring station, winds were from the west-southwest to north directions approximately 46% of the time, and from the east-southeast to south directions about 28% of the time.

➢ *Fort Saskatchewan, Fort McMurray, and Fort MacKay*

At the Fort Saskatchewan monitoring station, winds predominantly had a west to north-northwest component (33% of the time) or a southwest component (24% of the time). At Fort McMurray and Fort MacKay, the wind direction frequency distribution reflected the north-south orientation of the Athabasca River Valley in the two communities. Winds at Fort McMurray were from the north-northwest to north directions 28% of the time, and from the south-southeast to southeast directions 29% of the time. At the Fort MacKay station, winds were form the north-northwest to north-northeast directions (28% of the time) and from the south-southwest to south-southeast directions (33% of the time).

➢ *Springbank Airport and Royal Park*

Winds at the Springbank Airport station were predominantly from the west to northwest directions (28% of the time) and from the south-southeast to southeast directions (11% of the time). The wind direction frequency distribution is much more uniform at the Royal Park station with 21% of the winds from the west to southwest directions, 12% from the south to south-southeast directions, and 18% of the winds having a northeast component.

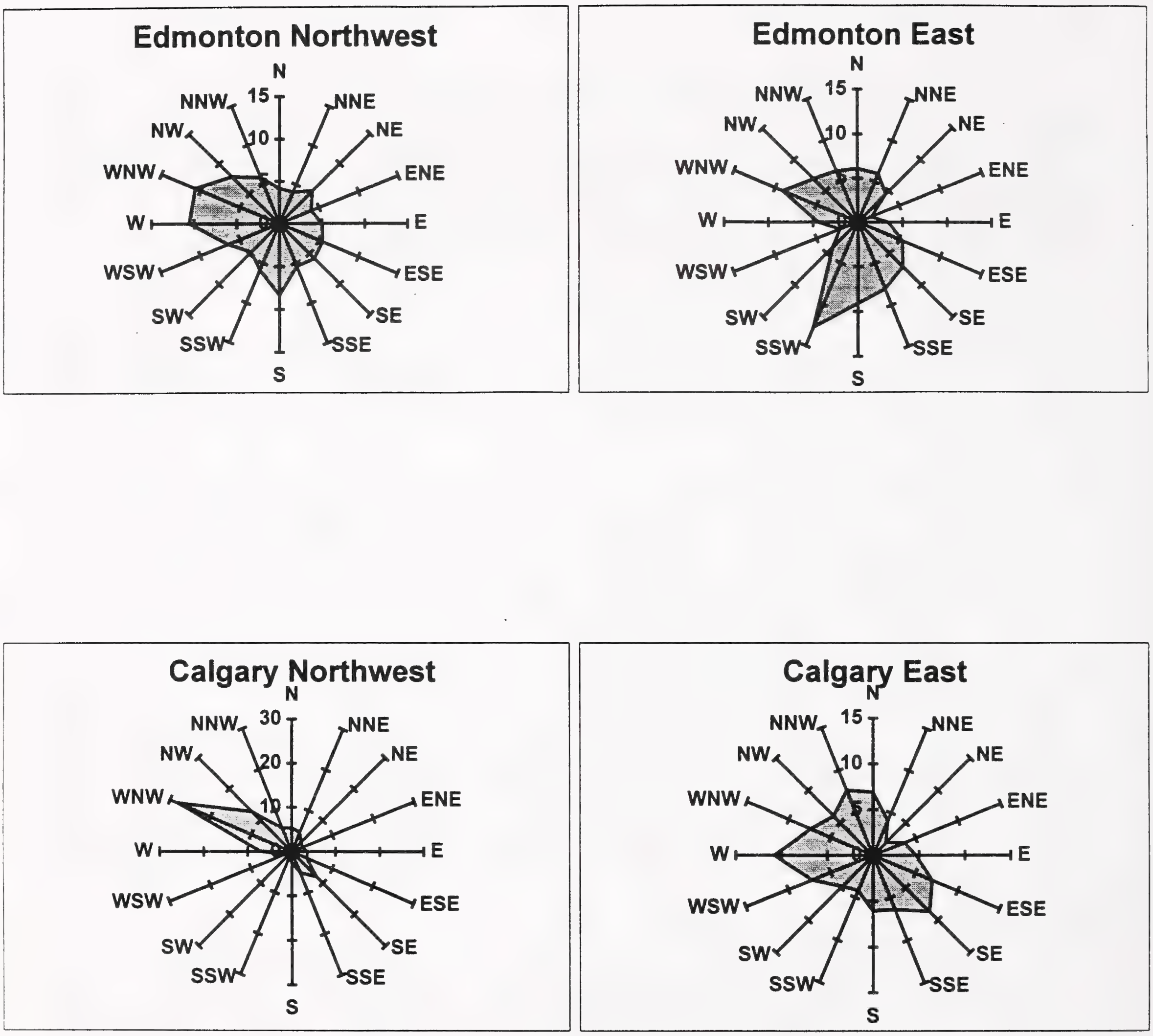


Figure 4-4 Frequency distributions of wind direction at Edmonton and Calgary monitoring stations in 1996.

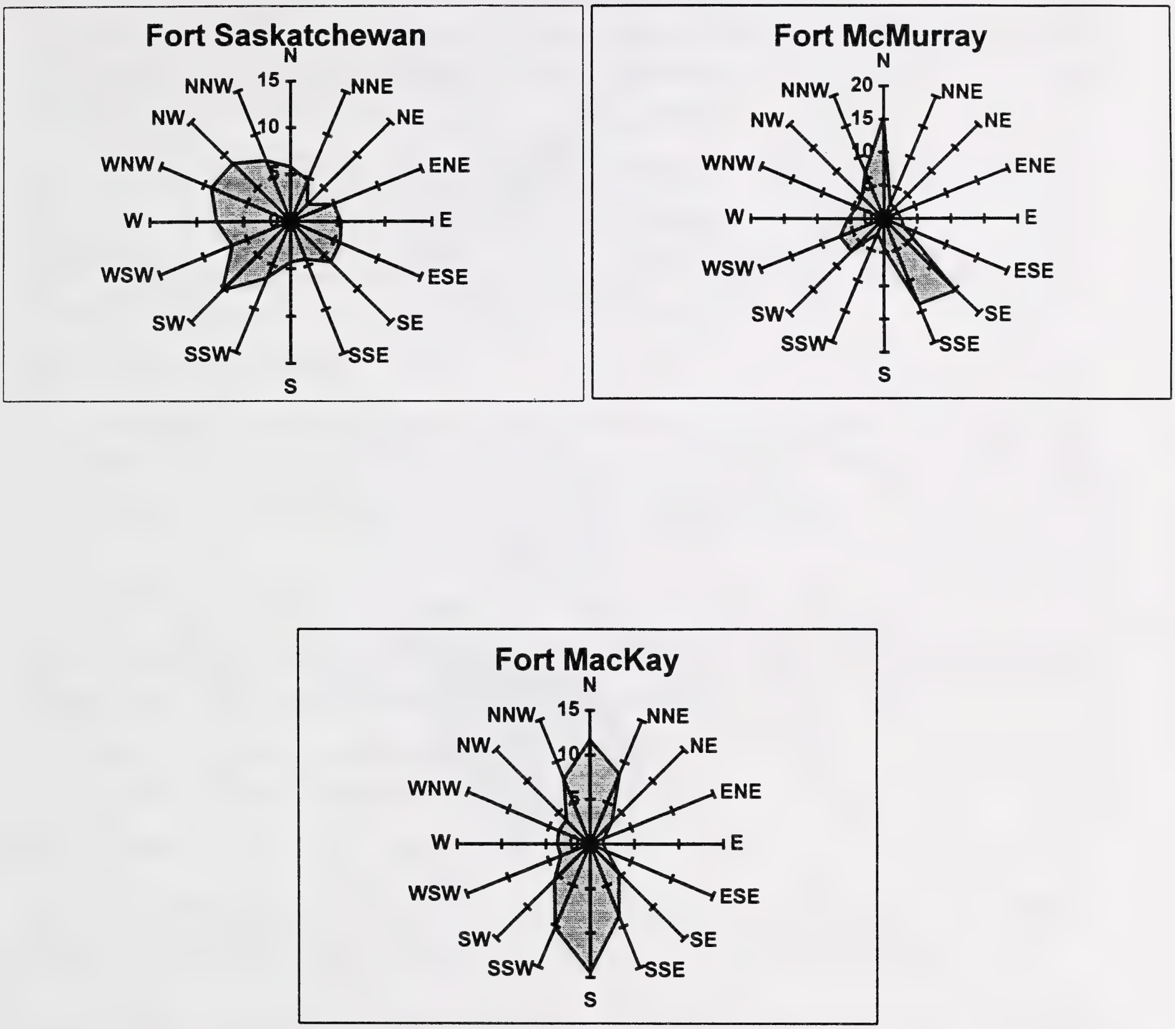
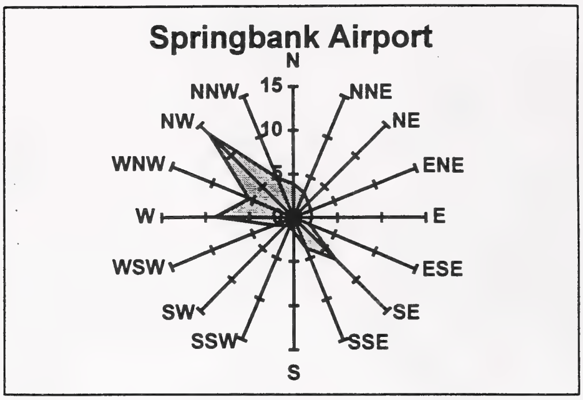


Figure 4-5 Frequency distributions of wind direction at Fort Saskatchewan, Fort McMurray and Fort MacKay in 1996.



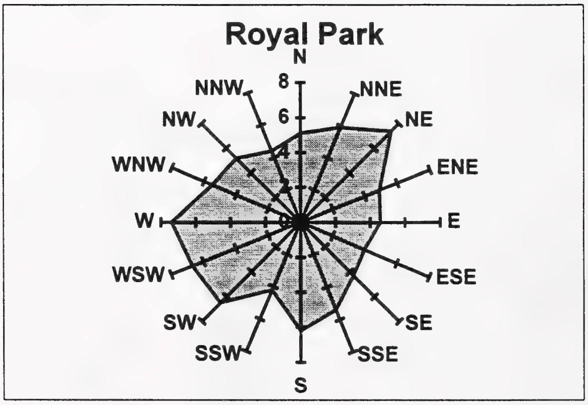


Figure 4-6 Frequency distribution of wind directions at Springbank and Royal Park monitoring stations in 1996.

4.3 CARBON MONOXIDE (CO)

4.3.1 Characteristics

CO, a common pollutant in urban areas, is a colourless, odourless gas. The majority of the CO found in urban air comes from incomplete combustion of carbon-based fuels. The major source of urban CO is motor vehicles, with much smaller contributions from industrial sources, aircraft, fireplaces and natural gas combustion (heating of homes).

The relationship between vehicular traffic and CO is apparent at urban locations during morning and evening rush hours. CO concentrations also fluctuate seasonally. The highest concentrations occur during the late autumn, winter and early spring primarily because of meteorological conditions, such as temperature inversions and low wind speeds which result in decreased pollutant dispersion. Other factors which contribute to higher concentrations during the autumn and winter are: (1) motor vehicles run less efficiently in cold weather; and (2) increased vehicle warm-up and idling times.

4.3.2 Method of Monitoring

CO is monitored continuously by either non-dispersive infrared photometry or gas filter correlation. The non-dispersive infrared photometry process is based upon the absorption of infrared light by CO. Gas filter correlation is operated on the same principle as non-dispersive infrared photometry but is more specific to CO by eliminating water vapour, CO_2 and other interferences.

4.3.3 Guidelines

The guidelines for the maximum permissible concentration of CO are based on the prevention of adverse human health effects. Alberta has adopted Environment Canada's most rigorous ambient air quality objective for CO. Maximum permissible CO concentrations are:

- 13.0 ppm as a 1-hour average concentration; and
- 5.0 ppm as an 8-hour average concentration.

4.3.4 Results

CO was monitored, on a continuous basis, at all three Edmonton and Calgary air quality stations, and at the Fort Saskatchewan and Fort McMurray monitoring stations. Frequency distributions of monthly CO concentrations and annual average CO concentrations are presented in Figures 4-7 to 4-9.

Concentrations of CO were generally greater in the vicinity of areas with high traffic density. The greatest annual average CO values were recorded at Edmonton Central, Edmonton Northwest, Calgary Central and Calgary East monitoring stations. The lowest average CO values were recorded at Edmonton East and Fort McMurray monitoring stations where automobile traffic was low compared to the other stations.

CO concentrations were generally higher in the autumn and winter months than the spring and summer months. In the winter, temperature inversions are more likely to persist throughout the day due to a lack of solar heating. Persistent inversions coupled with longer vehicular warm-up and idling times lead to increased CO concentrations during the late autumn and winter months. Most strong temperature inversions in Calgary occur prior to a chinook. Once the warm air of the chinook reaches ground-level, air pollutants will disperse rapidly.

A well-defined diurnal variation of CO concentrations was evident at most air quality monitoring stations. CO peaks were evident during the morning and afternoon traffic rush hours. The lowest CO values were generally recorded overnight when vehicular traffic is at a minimum.

All Alberta monitoring stations, with the exception of Fort McMurray and Edmonton East stations, show a long-term downward trend in annual average CO concentrations based on data collected from 1976 to 1996. This trend is most prevalent at stations near major traffic areas. More efficient emission control devices on newer automobiles are the major contributor to these lower CO values.

➢ *Edmonton*

The 1-hour guideline for CO was not exceeded at any of the Edmonton monitoring stations in 1996. Maximum 1-hour average CO concentrations were 7.9, 11.8, and 4.9 ppm at the Central, Northwest and East monitoring stations, respectively. The 8-hour guideline for CO was exceeded 2 times at the Northwest monitoring station. Winds were from the east to south-southwest over 62% of the time and west to west-northwest 25% of the time when exceedances of the 8-hour guideline were recorded at the Edmonton Northwest station. The primary source of CO at the Northwest station is vehicle exhaust emissions from major traffics arteries in northwest Edmonton (e.g. 127 Street, 137 Street and Yellowhead Trail). As in previous years, CO continues to show a downward trend at the Edmonton Central and Northwest monitoring stations.

➢ *Calgary*

The 1-hour guideline for CO was exceeded at the Calgary Central monitoring station twice in March of 1996. The 8-hour guideline for carbon monoxide was exceeded 4 times at both the Central and East monitoring stations. Winds from the south to west occurred over 75% of the time when exceedances of the 8-hour guideline were recorded at the Calgary East monitoring station. Wind is not measured at the Central station. A long-term downward trend in CO is indicated at all Calgary monitoring stations.

➢ *Fort Saskatchewan*

Concentrations of CO were substantially lower than the 1- and 8-hour guidelines at the Fort Saskatchewan monitoring unit in 1996. The maximum 1-hour average CO concentration recorded was 4.6 ppm which is 35% of the guideline. A downward trend in annual average CO is evident based on 15 years of data collected in Fort Saskatchewan. However, the Fort Saskatchewan station was moved several times within this time period.

➢ *Fort McMurray*

The maximum 1-hour value for CO recorded at the Fort McMurray monitoring unit was 4.1 ppm. This value is 31% of the 1-hour guideline. The 1- and 8- hour guidelines for CO were not exceeded at the Fort McMurray monitoring station. Annual average CO data collected at Fort McMurray does not show a significant historical trend.

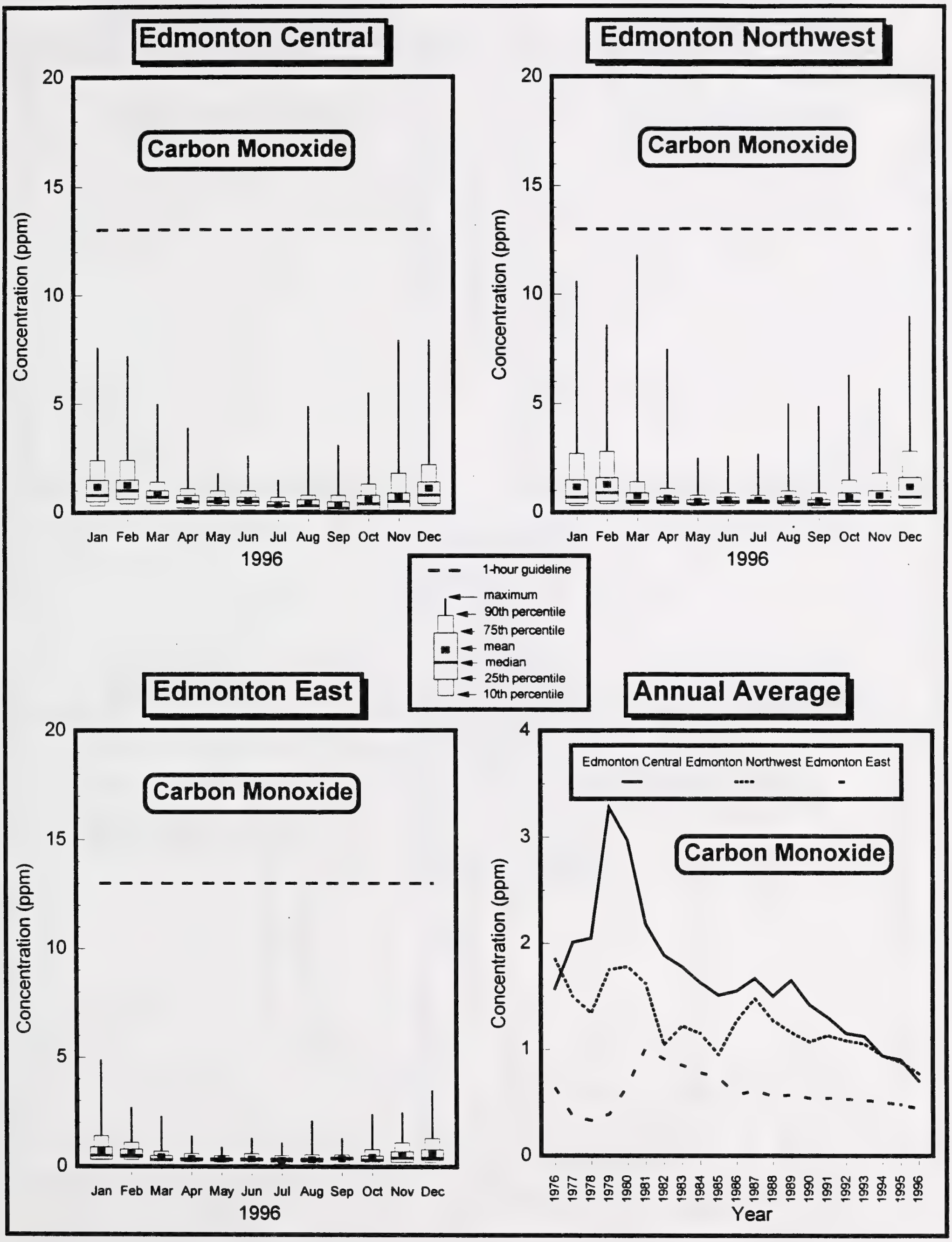


Figure 4-7 Frequency distribution of carbon monoxide concentrations at Edmonton.

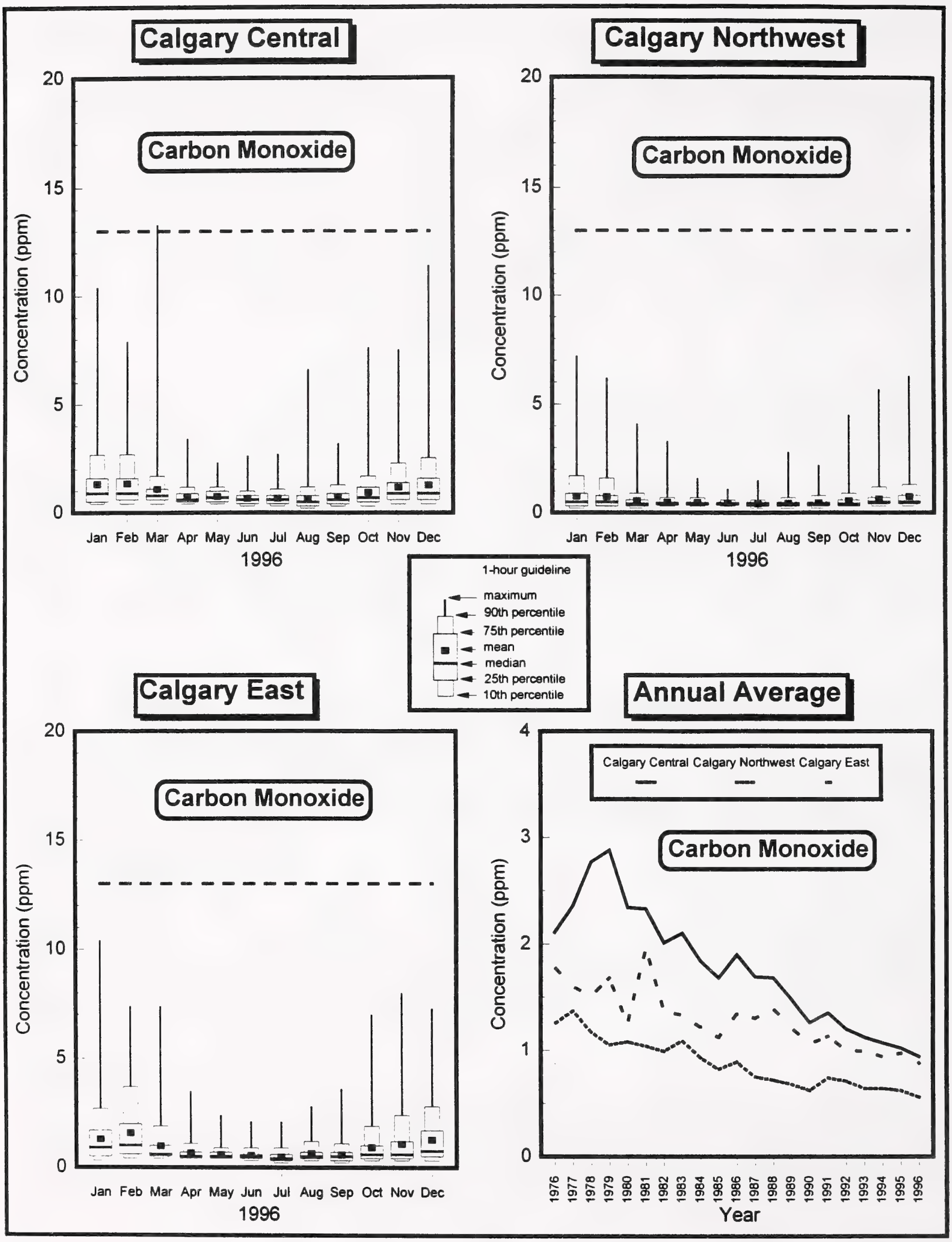


Figure 4-8 Frequency distribution of carbon monoxide concentrations at Calgary.

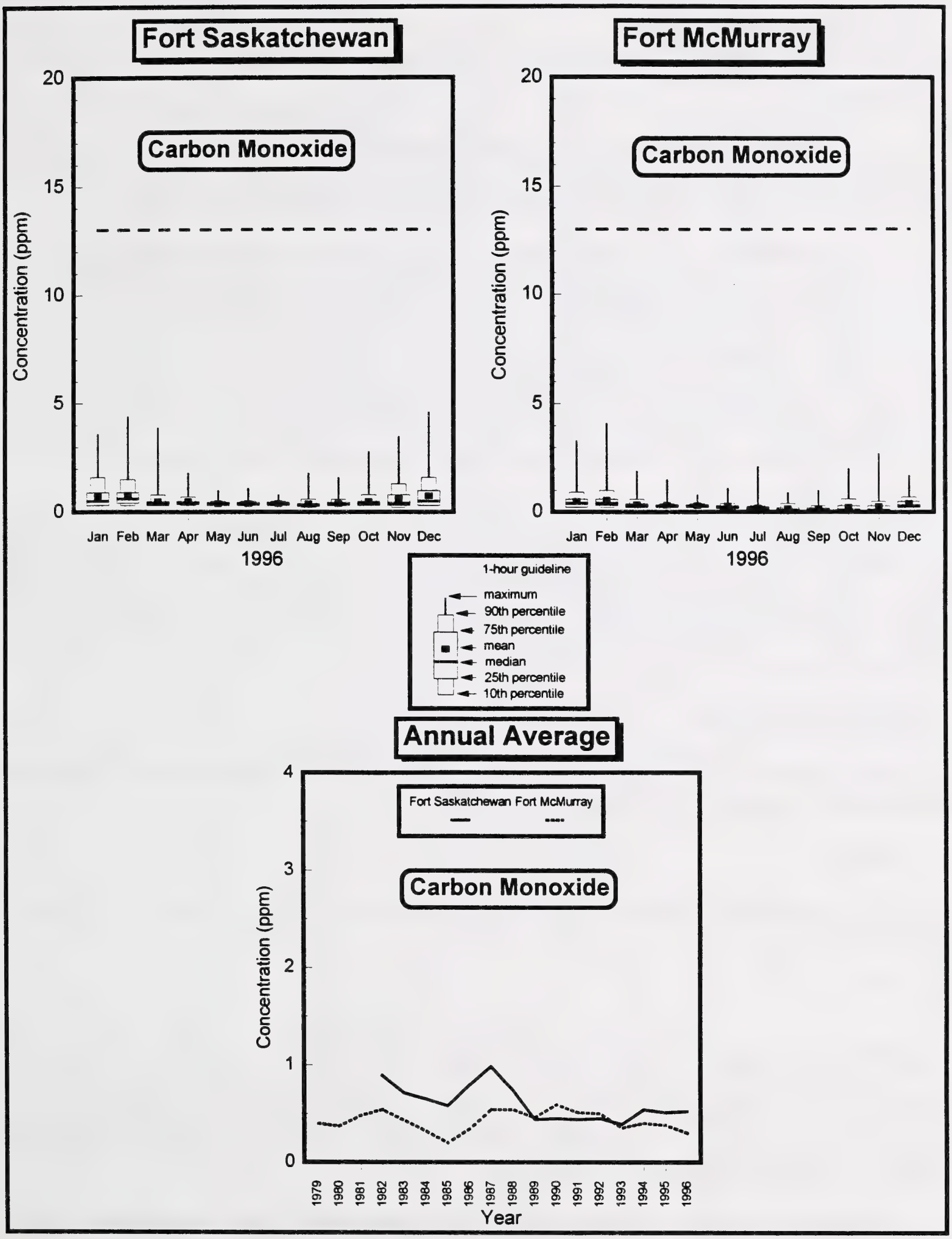


Figure 4-9 Frequency distribution of carbon monoxide concentrations at Fort Saskatchewan and Fort McMurray.

4.4 CARBON DIOXIDE (CO_2)

4.4.1 Characteristics

CO_2 is a colourless, odourless, non-toxic gas that is produced during the combustion of carbon-containing compounds. CO_2 is absorbed by trees and other vegetation through photosynthesis. Some CO_2 is re-emitted to the atmosphere by plants, animals and micro-organisms through respiration.

Increasing atmospheric CO_2 concentrations on a global level have been suggested to be a major contributor to an enhanced greenhouse effect. Solar radiation passes through the atmosphere and is absorbed by the earth's surface. Heat is then re-radiated by the earth's surface into the atmosphere. Greenhouse gases such as water vapour and CO_2 absorb this reflected heat and thus warm the atmosphere. Heat is essentially trapped in the atmosphere by greenhouse gases such as CO_2. Without this natural greenhouse effect, life as we know it would not exist on earth. Emissions of CO_2 from human activities increase global concentrations of CO_2 and may enhance this greenhouse effect contributing to additional heating of the atmosphere. Carbon dioxide makes up over half of the greenhouse gases emitted by human activities. Other greenhouse gases include methane, chlorofluorocarbons, nitrous oxide and ozone.

Approximately 152 megatonnes of CO_2 were emitted in Alberta by anthropogenic sources in 1995. This is about 30% of total CO_2 emissions for Canada. Power generation was responsible for 32% of CO_2 emissions in Alberta while fuel combustion by industrial, commercial (commercial buildings) and residential sources (houses, apartments and business) accounted for 20% of total CO_2 emissions. Industrial processes and transportation were responsible for about 12% and 15%, respectively, of CO_2 emitted in Alberta in 1995 (Environment Canada, 1996 draft report). These figures do not take into account natural sources of CO_2.

4.4.2 Method of Monitoring

Carbon dioxide is monitored continuously by non-dispersive infrared photometry. This detection process is based on the absorption of infrared light by CO_2.

4.4.3 Guidelines

At the present time, Alberta Environmental Protection does not have guidelines for ambient concentrations of CO_2.

4.4.4 Results

Monitoring for CO_2 by Alberta Environmental Protection began at the Calgary Central monitoring station in March of 1991. An additional CO_2 monitoring station was established at Springbank (20 km west-northwest of downtown Calgary) in August of 1991. This station was added to monitor CO_2 concentrations upwind of Calgary. In 1996, CO_2 was monitored at the Springbank station from January to June, inclusive. Figure 4-10 shows the frequency distribution of CO_2 concentrations at the Calgary Central and Springbank monitoring sites.

Annual average CO_2 concentrations at the Central and Springbank monitoring stations were 392 and 378 ppm (January to June), respectively. Average CO_2 concentrations were above those observed at Crossfield, about 40 km north of Calgary, and Fortress Mountain, about 85 km west-southwest of Calgary, during the Acid Deposition Research Program from 1985 to 1987. Annual average concentrations observed at these locations ranged from 345 to 349 ppm (Legge 1988). Higher CO_2 concentrations in downtown Calgary are due to heating fuel and gasoline combustion in Calgary and the

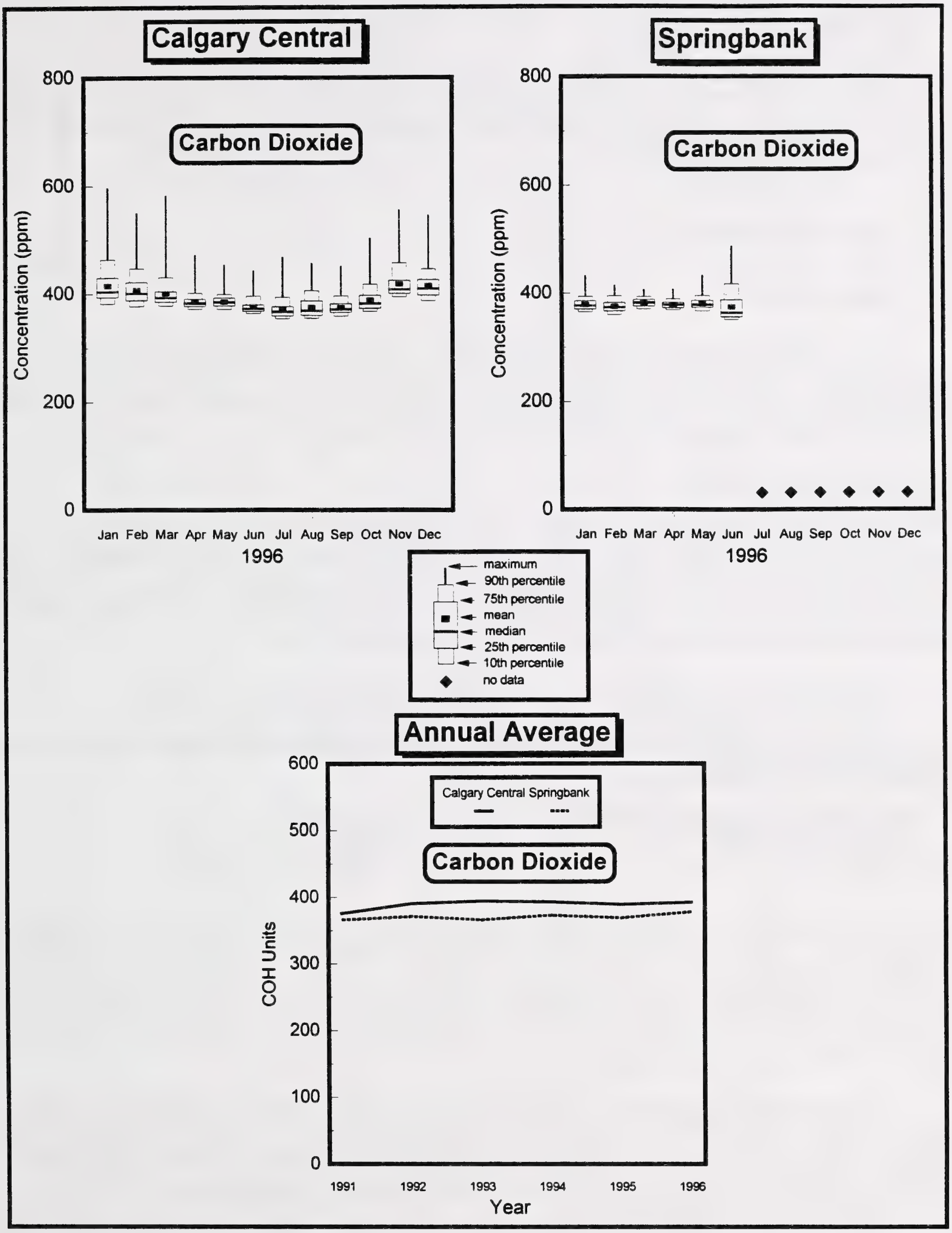


Figure 4-10 Frequency distribution of carbon dioxide concentrations at Calgary and Springbank.

surrounding area. Typical global CO_2 concentrations measured at remote locations are about 345 ppm (Bolin et al, 1986).

Overall maximum 1-hour average CO_2 concentrations at the Calgary Central and Springbank monitoring stations were 597 and 487 ppm, respectively. The highest CO_2 concentrations were generally observed in the fall and winter at the Central station. The peak 1-hour average concentrations were recorded in June at the Springbank site.

4.5 DUST AND SMOKE

4.5.1 *Characteristics*

The coefficient of haze (COH) is an indicator which corresponds to the amount of dust and smoke in the atmosphere. Sources of dust and smoke include motor vehicle emissions, industrial emissions, road dust, wind blown soil, dust resulting from other human activities (i.e., agriculture), smoke from forest fires, and smoke from recreational sources (i.e., camp fires and fireplaces).

4.5.2 *Method of Monitoring*

Air samples are collected by continuously drawing a known volume of air through a filter paper for a period of one hour. The soiling properties of the sample are measured by the reduction of light transmission through the filter tape. This reduction is reported as the coefficient of haze per 1000 linear feet of air sample. This method does not measure the absolute concentration or deposited mass of particulates but rather is an indicator of particulate matter suspended in the air.

4.5.3 *Guidelines*

Guidelines regarding the COH are based on visibility reduction. Alberta Environmental Protection has established that:

- 90% of the COH readings per month shall be less than 1.0 COH unit.

4.5.4 *Results*

Dust and smoke was monitored at all Edmonton, Calgary, Fort Saskatchewan and Fort McMurray monitoring units. Annual average dust and smoke indices ranged from 0.07 COH units at the Fort McMurray station to 0.29 COH units at the Calgary East station. Relatively high annual average values were also recorded at the Edmonton Northwest and the Calgary Central (0.21 COH units) locations. The major sources of dust and smoke in urban areas are vehicular and industrial emissions, and dust from the streets (especially in the winter and early spring).

A seasonal trend indicating higher dust and smoke levels during the winter and autumn seasons is obvious at most stations. Meteorological conditions in the winter and autumn months are often favourable for the accumulation of pollutants within the lower atmosphere. Longer idling times of vehicles also contribute to higher COH readings in the winter months.

A diurnal trend is evident at stations which are located in the vicinity of major traffic arteries such as the Edmonton stations and the Calgary central station, or that are affected by vehicle emissions being transported to the monitoring location (the Calgary East station). Substantial maximums in dust and smoke values were recorded during the morning and afternoon rush hours. This diurnal tendency is not as prevalent at Fort Saskatchewan and Fort McMurray, where vehicular traffic is much lower than in Edmonton and Calgary. Frequencies and annual average trends of dust and smoke values are presented in Figures 4-11 to 4-13.

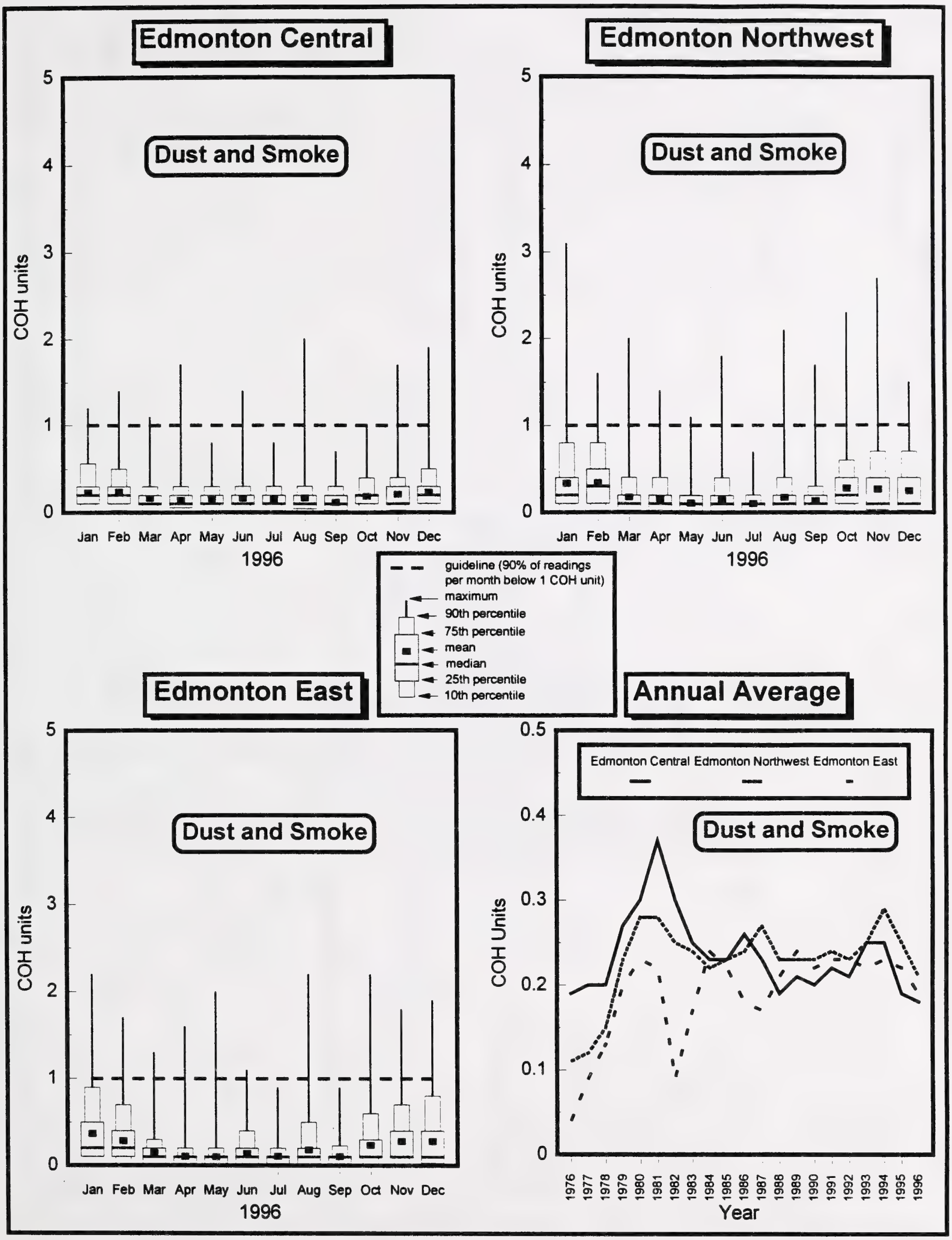


Figure 4-11 Frequency distribution of dust and smoke values at Edmonton.

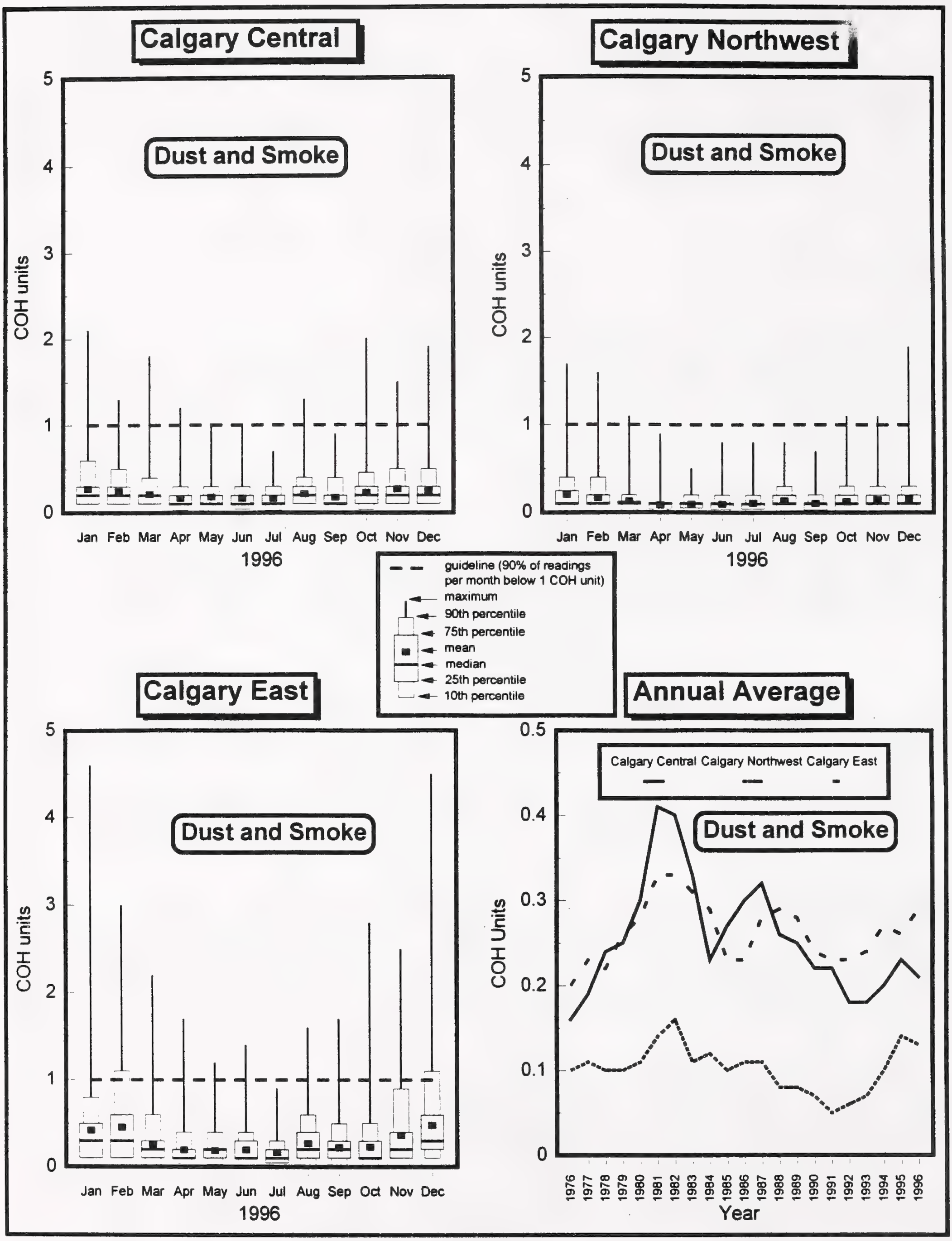


Figure 4-12 Frequency distribution of dust and smoke values at Calgary.

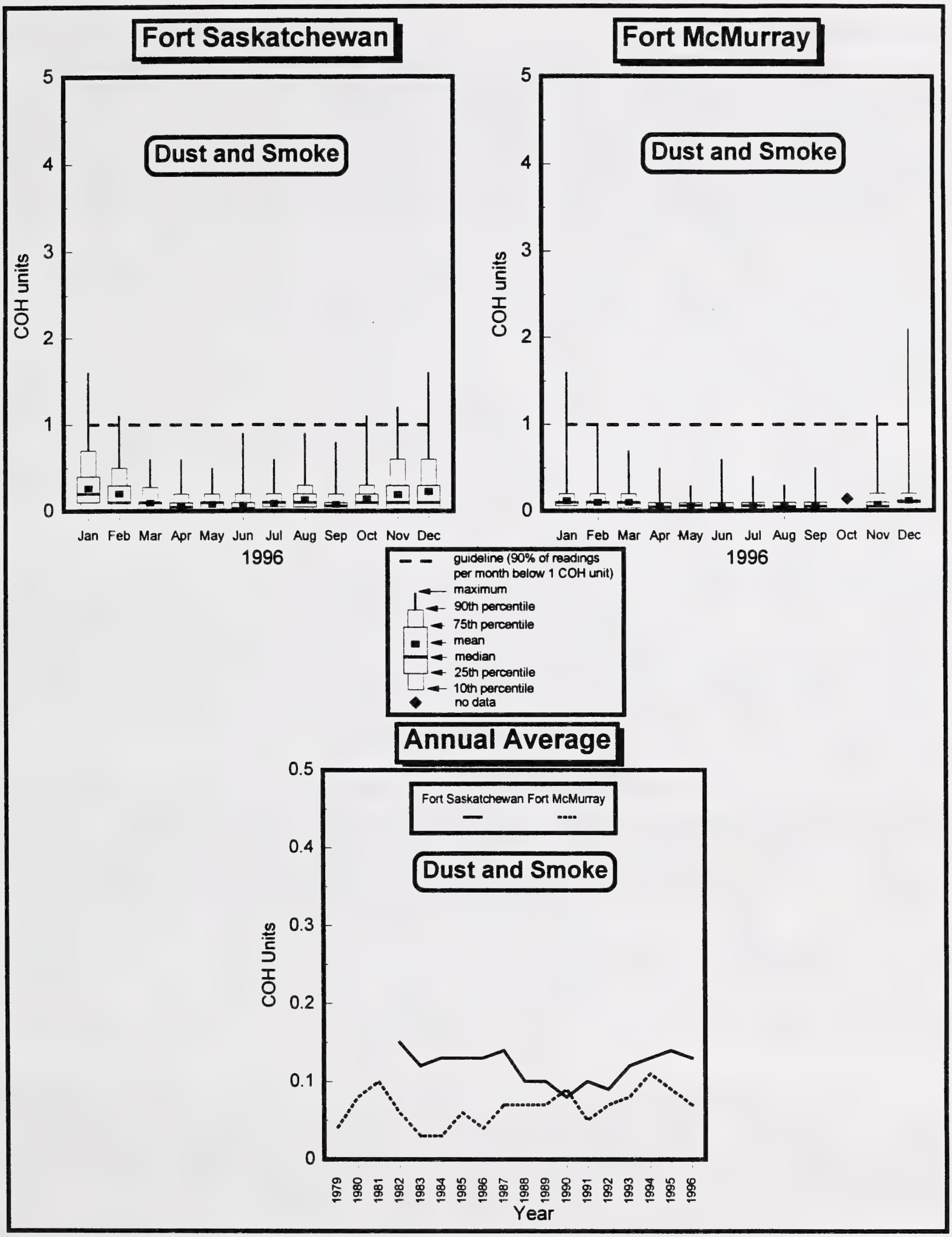


Figure 4-13 Frequency distribution of dust and smoke values at Fort Saskatchewan and Fort McMurray.

- ***Edmonton***

  The guideline for the COH (90% of COH values per month must be less than 1.0 COH unit) was not exceeded at any of the Edmonton monitoring stations. The majority of the winds were from the south to west-southwest directions (67% of the time) when the COH values were greater than 1.0 COH unit at the Northwest station. Winds were from the south to southwest directions close to 80% of the time when values greater than 1.0 COH unit were recorded at the East station. COH values greater than 1.0 COH unit can be attributed to the combination of vehicle exhaust emissions and stagnant weather conditions. A maximum 1-hour COH value of 2.0, 3.1 and 2.2 COH units were recorded at the Central, Northwest and East stations, respectively. An increase in annual average COH values is evident at the Edmonton East monitoring station based data from 1976. This increase is likely due to more traffic along major traffic arteries near the station (17 Street, Baseline Road).

- ***Calgary***

  The guideline for the COH (90% of COH values per month must be less than 1.0 COH unit) was exceeded two times at the Calgary East monitoring station in 1996. The frequency of values above 1.0 COH unit was 11.6% in February and 11.02% in December. The monthly guideline for the COH was not exceeded at any of the other Calgary stations. An overall maximum 1-hour average COH value of 4.6 COH units was recorded in January at the East station. A statistically significant trend in annual average COH values is not evident at any of the other Calgary stations.

- ***Fort Saskatchewan***

  The guideline for COH was not exceeded in Fort Saskatchewan in 1996. The highest monthly frequency of COH values greater than 1.0 COH unit was 2.4% which occurred in December at the Fort Saskatchewan monitoring station. The overall maximum COH value was 1.6 COH units in December and January. A trend in annual average COH values is not evident at the Fort Saskatchewan monitoring station.

- ***Fort McMurray***

  The guideline for COH was not exceeded at the Fort McMurray monitoring station in 1996. The highest frequency of values greater than 1.0 COH unit was 0.2% which occurred in November. The maximum 1-hour COH value was also recorded in December at the Fort McMurray monitoring station (2.1 COH units). A small upward trend in annual average COH values is indicated at Fort McMurray. This increase is likely related to more traffic in the vicinity of the monitoring station.

4.6 HYDROGEN SULPHIDE (H_2S)

4.6.1 Characteristics

H_2S is a colourless gas with a characteristic rotten egg odour. H_2S is produced both naturally and through industrial processes. H_2S is found naturally in coal, natural gas, oil, sulphur hot springs, sloughs, swamps and lakes. It is also produced under anaerobic conditions in the decomposition of sulphur-containing bacteria. Decomposition of sulphur-containing bacteria is responsible for the rotten egg odour commonly associated with sewers, sewage lagoons and marshes.

While most of the H_2S in the atmosphere is from natural sources, industrial sources also emit significant amounts of H_2S. These industrial sources are primarily petroleum refining, natural gas plants, petrochemical complexes, coke oven plants, and pulp and paper mills employing the kraft pulping process.

4.6.2 Method of Monitoring

H_2S is measured continuously by pulsed fluorescence (the same principle as the SO_2 analyzer). Initially, all SO_2 in the air sample is scrubbed out so that it does not interfere with the measured H_2S concentrations. The remaining H_2S in the sample is then converted to SO_2. The sample is then drawn through a sample chamber where it is irradiated with pulses of ultra-violet light. Any SO_2 in the sample is excited to a higher energy level and upon returning to its original state, light or fluorescence is released. The amount of fluorescence measured is proportional to the SO_2 (converted from H_2S) concentration.

4.6.3 Guidelines

The guidelines for maximum permissible concentrations of H_2S are based on the odour threshold, although many individuals can smell H_2S at levels below the ambient guidelines. Alberta has adopted Environment Canada's most rigorous ambient objectives for maximum permissible H_2S concentrations:

- 0.010 ppm as a 1-hour average concentration; and
- 0.003 ppm as a 24-hour average concentration.

4.6.4 Results

H_2S is monitored at the Edmonton East, Calgary East, Fort Saskatchewan, Fort McMurray and Fort MacKay monitoring units. Percentile diagrams for monthly concentrations and annual average concentrations from these stations are presented in Figures 4-14 and 4-15.

Annual average H_2S concentrations were 0.001 ppm at the Edmonton and Calgary East monitoring stations. All other stations recorded annual average values below the limit of detection. Since H_2S concentrations were low at most locations, seasonal, diurnal and annual trends were not distinguishable, however, episodic exceedances of the guidelines were observed and are described below.

➢ Edmonton East

The 1-hour guideline for H_2S was exceeded 8 times at the Edmonton East monitoring station in 1996. This is compared to 5, 41, and 17 exceedances of this guideline in 1995, 1994, and 1993, respectively. These exceedances occurred in the evening of January 17 (3 hours) and 18 (1 hour), in the early morning of March 30 (2 hours), and in the early morning of August 10 (2 hours). Winds were from the north-northeast to northeast (25% of the time) and from the east-southeast to south-southeast directions (63% of the time) when exceedances of the 1-hour guideline were recorded. The overall maximum H_2S concentration of 0.034 ppm occurred in March and is over 3 times the guideline of 0.010 ppm. These exceedances were caused by fugitive emissions from local industrial sources such as petroleum storage tanks and transportation vehicles. The 24-hour regulation for H_2S was exceeded once in 1996 on January 17 at the Edmonton East station.

➢ Calgary East

There were no exceedances of the 1-hour guideline for H_2S at the Calgary East monitoring station in 1996. This is compared to 14 exceedances of the 1-hour guideline in 1995. The highest 1-hour H_2S concentration was 0.010 ppm and occurred on January 9, 1996. The 24-hour guideline was exceeded only once, also on January 9, with a 24-hour average concentration of 0.004 ppm. Sources of H_2S in southeast Calgary are primarily fugitive emissions from the sewage treatment plant.

➢ Fort Saskatchewan

The 1-hour guideline for H_2S was not exceeded at the Fort Saskatchewan monitoring station in 1996. The maximum 1-hour average concentration was 0.008 ppm which is 80% of the guideline. The 24-hour guideline was exceeded once on December 26. This exceedance may have been caused by

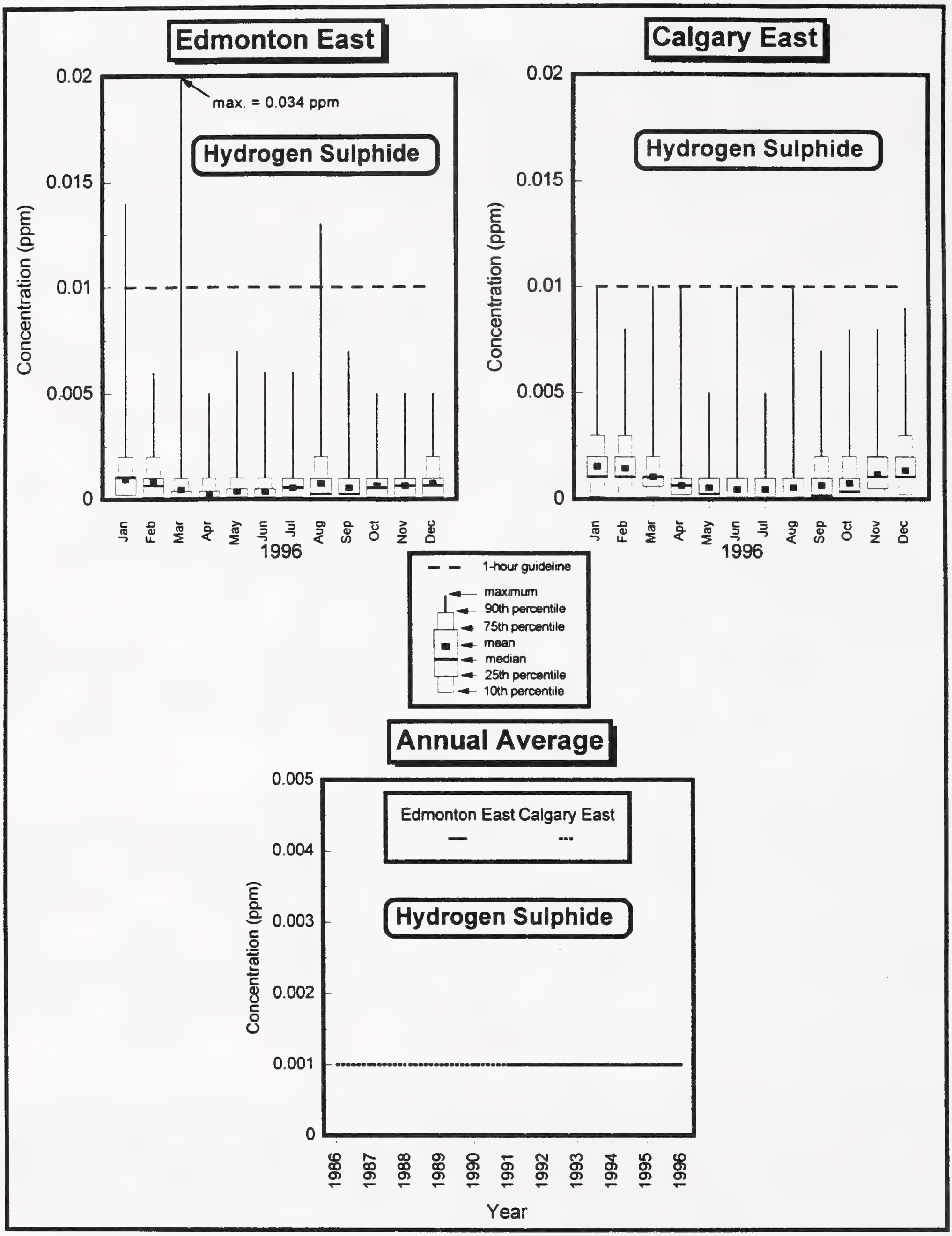


Figure 4-14 Frequency distribution of hydrogen sulphide concentrations at Edmonton and Calgary.

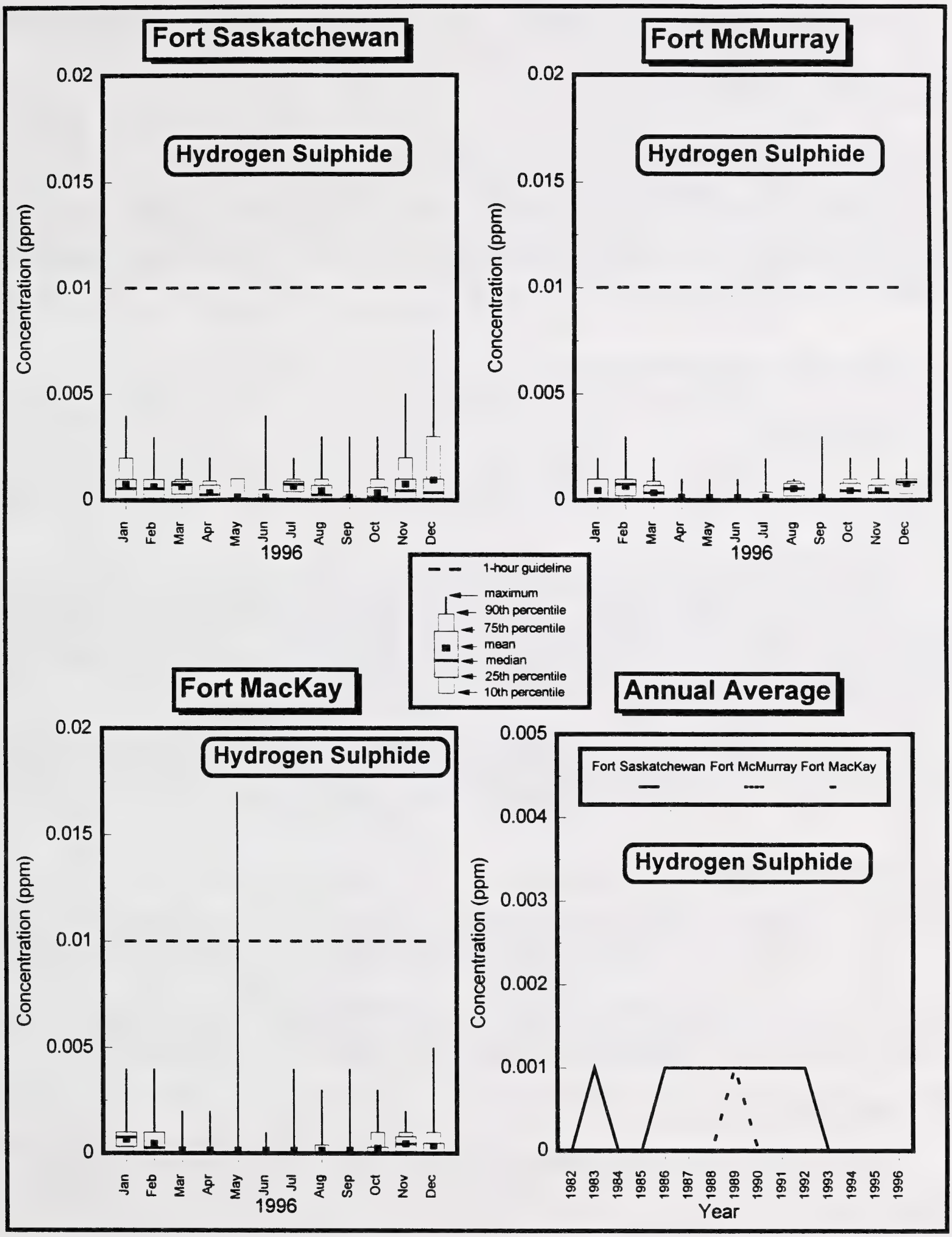


Figure 4-15 Frequency distribution of hydrogen sulphide concentrations at Fort Saskatchewan, Fort McMurray and Fort Mackay.

hydrogen sulphide transported from sources in the Edmonton area (industry or sewage treatment facility). Winds were from the southwest 71% of the time when this exceedance was reported.

➢ Fort McMurray and Fort MacKay

The 1-hour and 24-hour guidelines for H_2S were not exceeded at the Fort McMurray monitoring station in 1996. The maximum 1-hour value recorded at the Fort McMurray station was 0.003 ppm. This value is 30% of the guideline. At Fort MacKay, the 1-hour guideline for H_2S was exceeded once on the evening of May 26. The maximum value recorded at this time was 0.017 ppm. Winds were from the southeast when the 1-hour guideline was exceeded. The 24-hour guideline for H_2S was not exceeded at the Fort MacKay monitoring station. The sources of these exceedances were the oilsands facilities located south-southeast of the community.

4.7 OXIDES OF NITROGEN (NO_X)

4.7.1 Characteristics

Oxides of nitrogen exist in the ambient atmosphere as a combination of nitrogen dioxide (NO_2) and nitric oxide (NO). Alberta Environmental Protection monitors for NO_2, NO, and NO_X on a continuous basis.

During high temperature combustion, as in the burning of natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form NO. NO is colourless, odourless and has no known toxic effects. Most of the NO is rapidly oxidized to form NO_2. NO_2 is a reddish-brown gas with a characteristic pungent odour and is partially responsible for the brownish discolouration of the lower atmosphere near urban areas.

In Alberta, about 43% of anthropogenic NO_X emissions are contributed by transportation (vehicles and aircraft), 37% by the oil and gas industry and 18% by power plants. The remaining 2% originates from natural gas and heating fuel combustion used in heating homes and businesses (Deslauriers, 1995).

4.7.2 Method of Monitoring

Oxides of nitrogen are measured continuously by the principle of chemiluminescence. In this method, the air sample is split into two pathways. In the first pathway, the NO concentration is measured by mixing ozone with the sample and detecting the amount of visible light produced when NO reacts with O_3 to form NO_2. In the second pathway, all the NO_2 in the sample is reduced to NO by a catalytic converter adding to the NO already present. The total NO_X is measured by reacting all the NO in the second pathway with ozone. The difference between the two readings is the concentration of NO_2.

4.7.3 Guidelines

The guidelines for the maximum permissible concentration of NO_2 are based on the prevention of human health effects. Alberta has adopted the most rigorous ambient objectives set by Environment Canada for NO_2:

- 0.21 ppm as a 1-hour average concentration;
- 0.11 ppm as a 24-hour average concentration; and
- 0.03 ppm as an annual arithmetic average.

There are no guidelines for ambient concentrations of NO and NO_X.

4.7.4 Results

NO_2, NO and NO_X are monitored continuously at all Edmonton, Calgary, Fort Saskatchewan and Fort McMurray monitoring sites. Monitoring of oxides of nitrogen began at the Royal Park station in April, 1995.

In 1996, annual average NO_2 concentrations ranged from 0.006 ppm at Royal Park to 0.029 ppm at the Calgary Central monitoring station. The Edmonton Central (0.025 ppm), Edmonton Northwest (0.024ppm) and Calgary East (0.028 ppm) monitoring stations also recorded relatively high annual average NO_2 concentrations. Higher NO_2 concentrations at these locations were due primarily to vehicular exhaust emissions. Figures 4-16 to 4-18 show monthly frequency distributions for NO_2 at each monitoring location. Annual average concentrations are also presented in these figures.

Annual average NO concentrations ranged from 0.002 ppm at Royal Park to 0.043 ppm at the Calgary East monitoring station. Relatively high annual average NO concentrations were also evident at the Edmonton Central, Edmonton Northwest and Calgary Central monitoring stations (0.026, 0.028, and 0.028 ppm, respectively). NO is produced primarily by vehicles and industries, such as natural gas processing. Monthly frequency distributions and annual average NO concentrations are shown in Figures 4-19 to 4-21.

Total oxides of nitrogen (NO_X), which is the sum of NO_2 and NO, had annual average concentrations that ranged from 0.007 ppm at Royal Park to 0.071 ppm at the Calgary East monitoring station. Relatively high annual average NO_X concentrations were also observed at the Calgary Central (0.056 ppm), Edmonton Northwest (0.051 ppm) and Edmonton Central (0.050 ppm) monitoring stations. NO concentrations are generally higher than NO_2 values at monitoring stations located closer to vehicle emission sources. In 1996, annual average NO concentrations were higher than NO_2 concentrations at the Edmonton Central, Edmonton Northwest, Calgary East and Fort Saskatchewan monitoring stations. The Calgary Northwest, Fort McMurray and Royal Park stations were the only stations that recorded significantly higher annual average concentrations of NO_2 than NO. The remaining monitoring stations recorded annual average NO and NO_2 values that were approximately the same. Monthly frequency distributions of NO_X concentrations are displayed in Figures 4-22 to 4-24.

NO_2 concentrations are generally greater during the fall and winter seasons than during the other seasons of the year. In the winter season, persistent temperature inversions will retard the dispersion of pollutants and therefore, lead to higher pollutant concentrations. Automobile emissions and heating fuel consumption and also tend to be the highest during the winter season. This seasonal trend was also evident for NO, however, it was not as obvious as it was for NO_2.

A diurnal trend in NO_2 concentrations was evident at the Calgary and Edmonton urban loactions. NO_2 values tended to be at a minimum in the early morning hours. An increase in NO_2 concentrations was evident in the morning rush hour and again in the afternoon rush hour. Concentrations begin to drop again at about midnight. This diurnal trend is especially prevalent during the winter months. A diurnal trend is not apparent at more rural locations such as Fort Saskatchewan, Fort McMurray and Royal Park where vehicular emissions are substantially lower.

➢ *Edmonton*

The 1-hour, 24-hour and annual average guidelines for NO_2 were not exceeded at any of the Edmonton monitoring locations. Maximum 1-hour average NO_2 concentrations were 0.106, 0.162 and 0.085 ppm at the Central, Northwest and East monitoring units, respectively. These maximum values occurred in January at the Central and East stations, and in August at the Northwest station. The 1-hour guideline for NO_2 is 0.210 ppm.

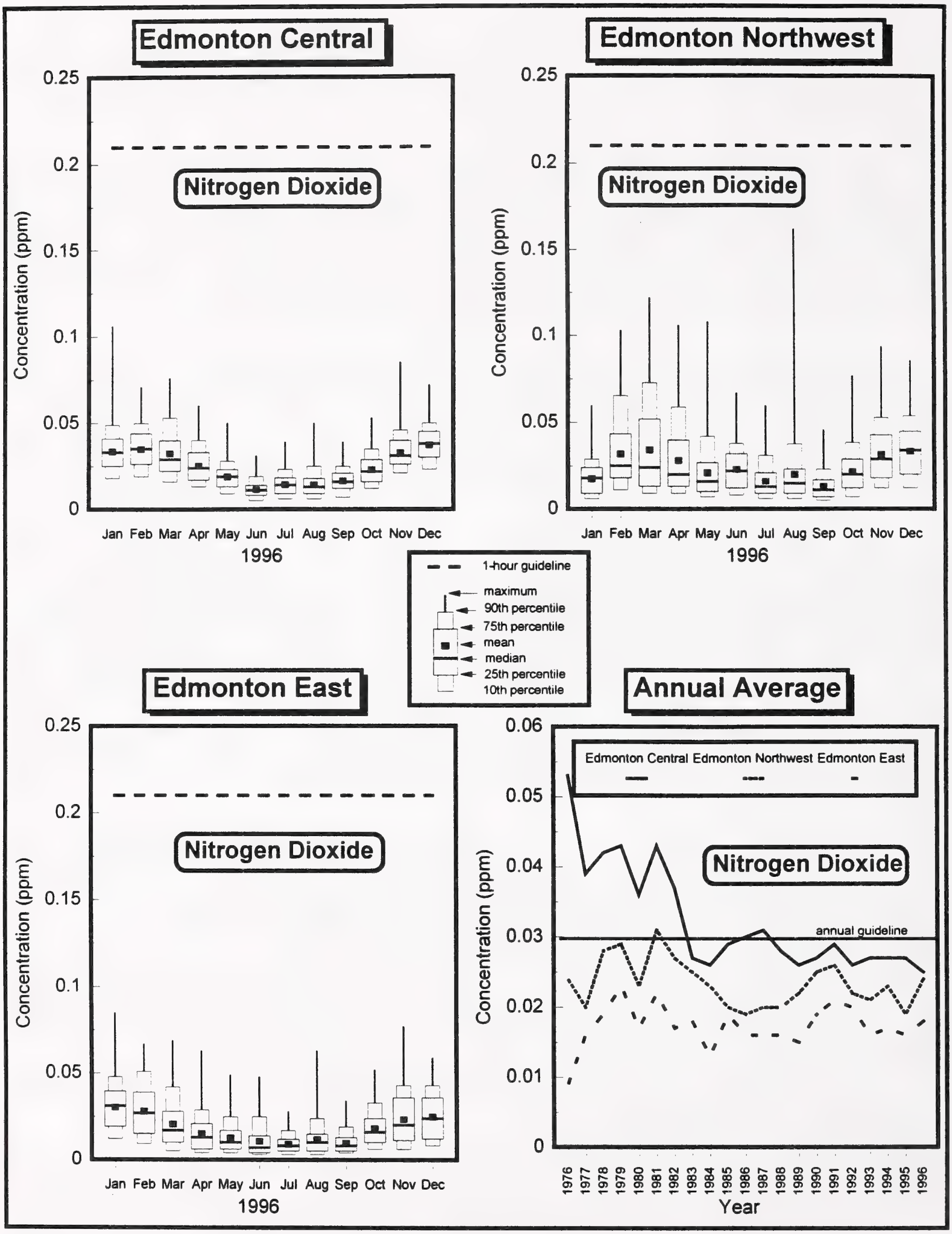


Figure 4-16 Frequency distribution of nitrogen dioxide concentrations at Edmonton.

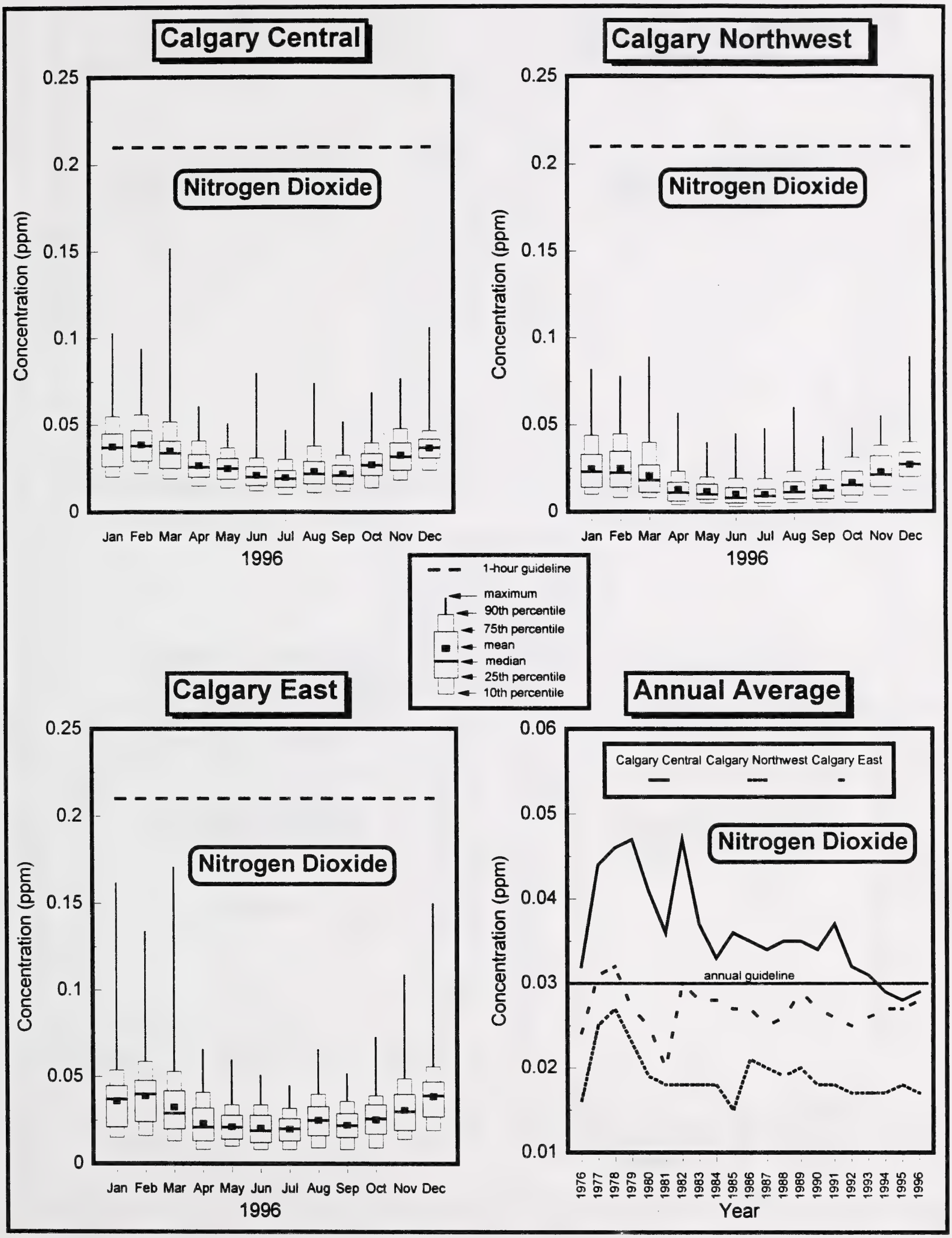


Figure 4-17 Frequency distribution of nitrogen dioxide concentrations at Calgary.

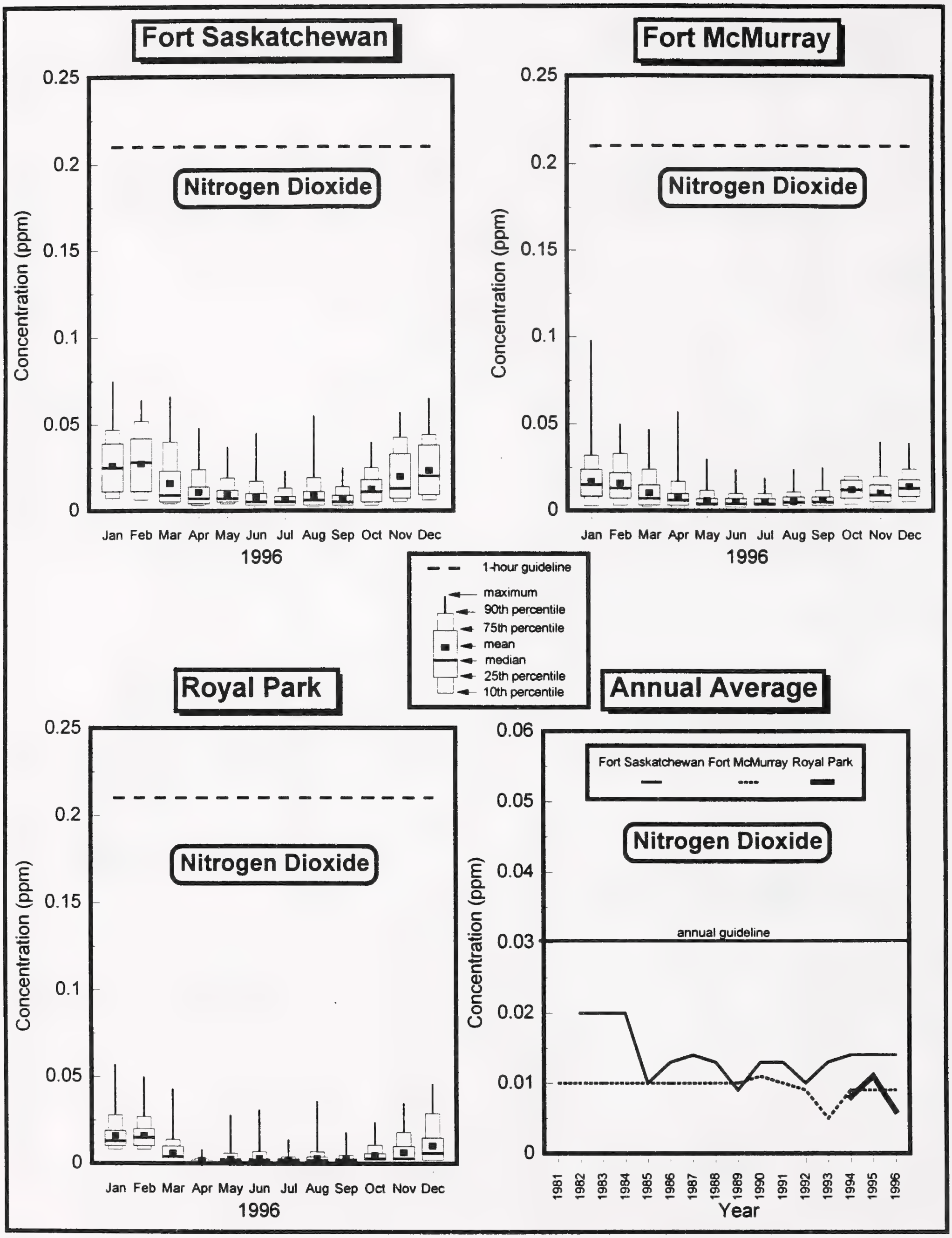


Figure 4-18 Frequency distribution of nitrogen dioxide concentrations at Fort Saskatchewan, Fort McMurray and Royal Park.

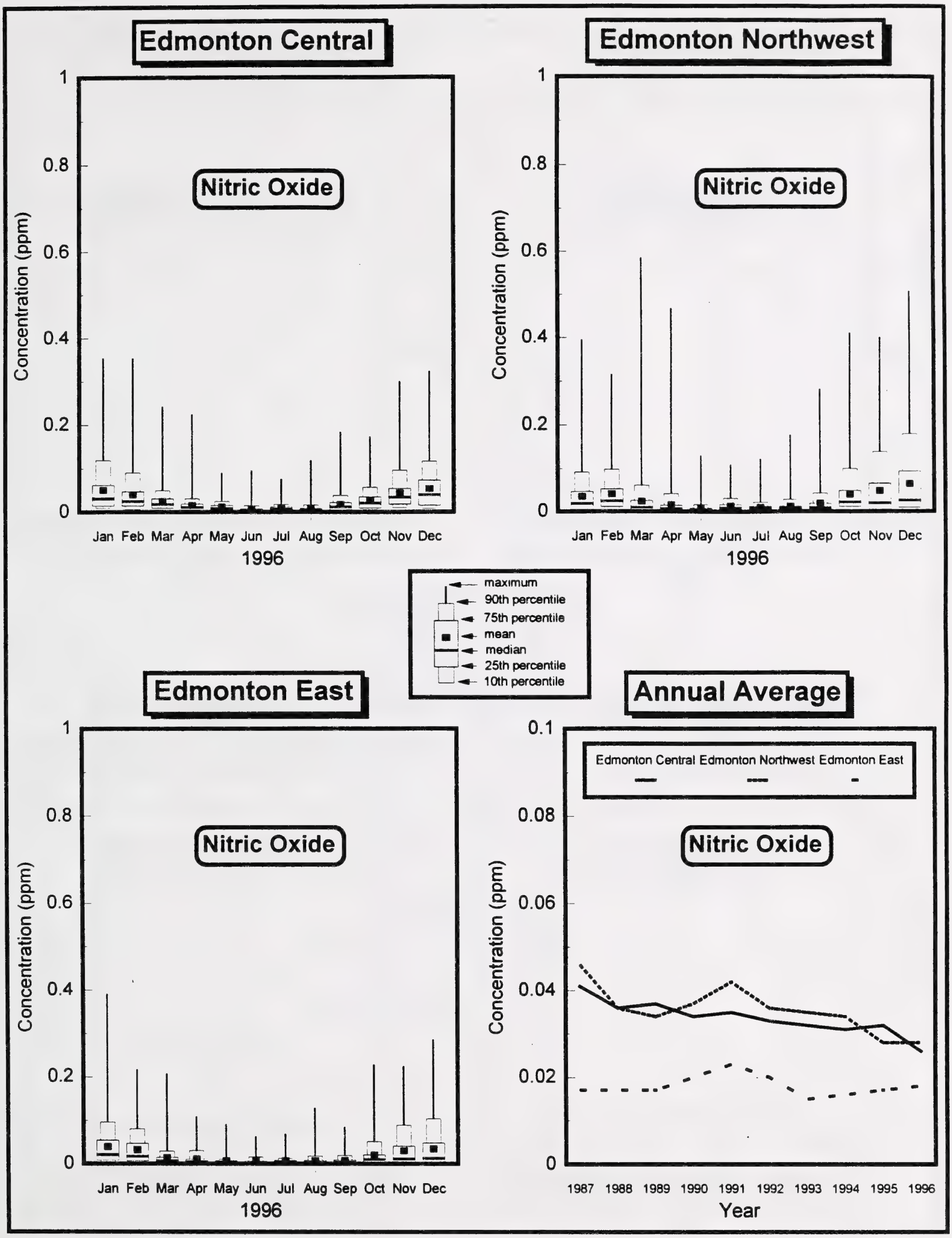


Figure 4-19 Frequency distribution of nitric oxide concentrations at Edmonton.

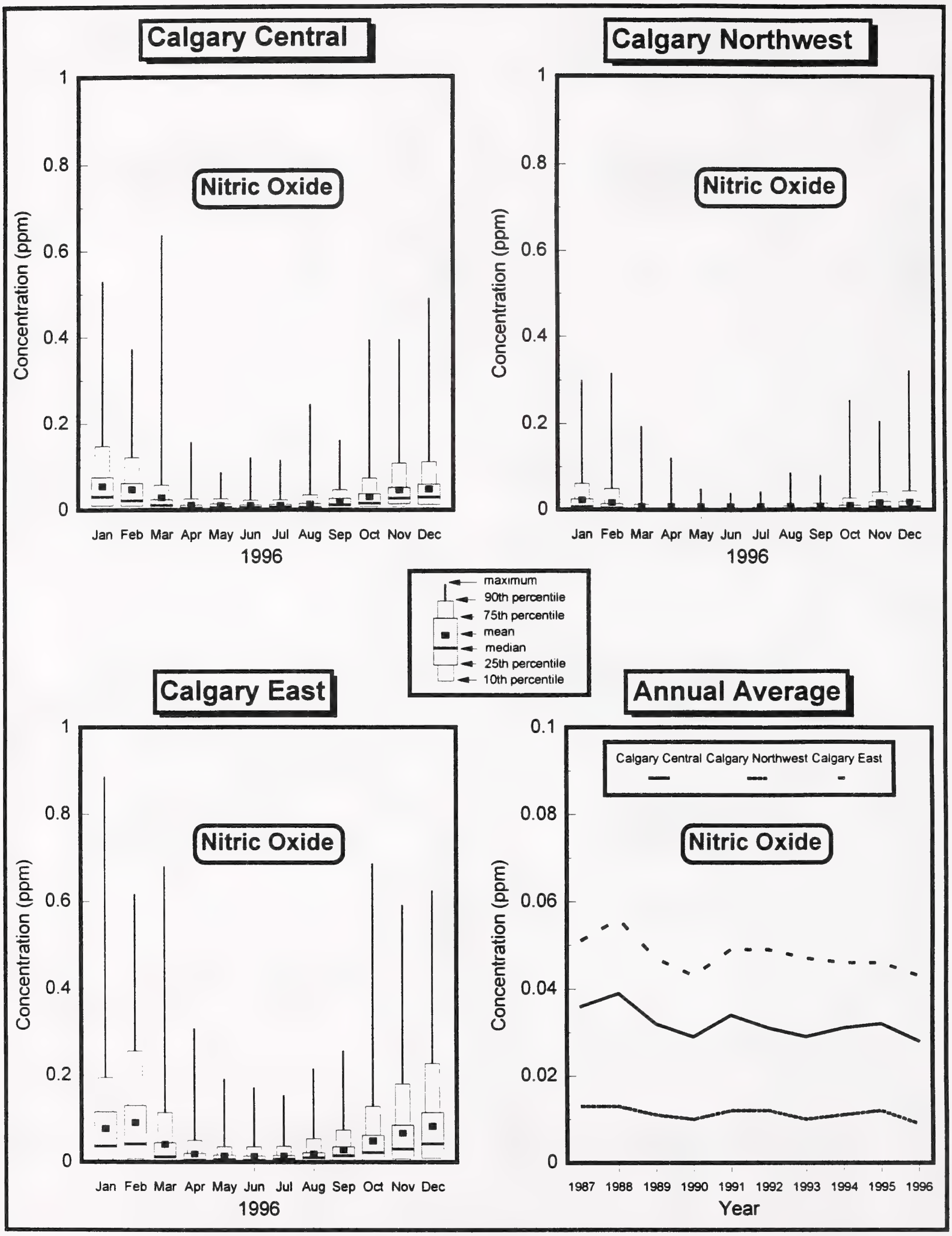


Figure 4-20 Frequency distribution of nitric oxide concentrations at Calgary.

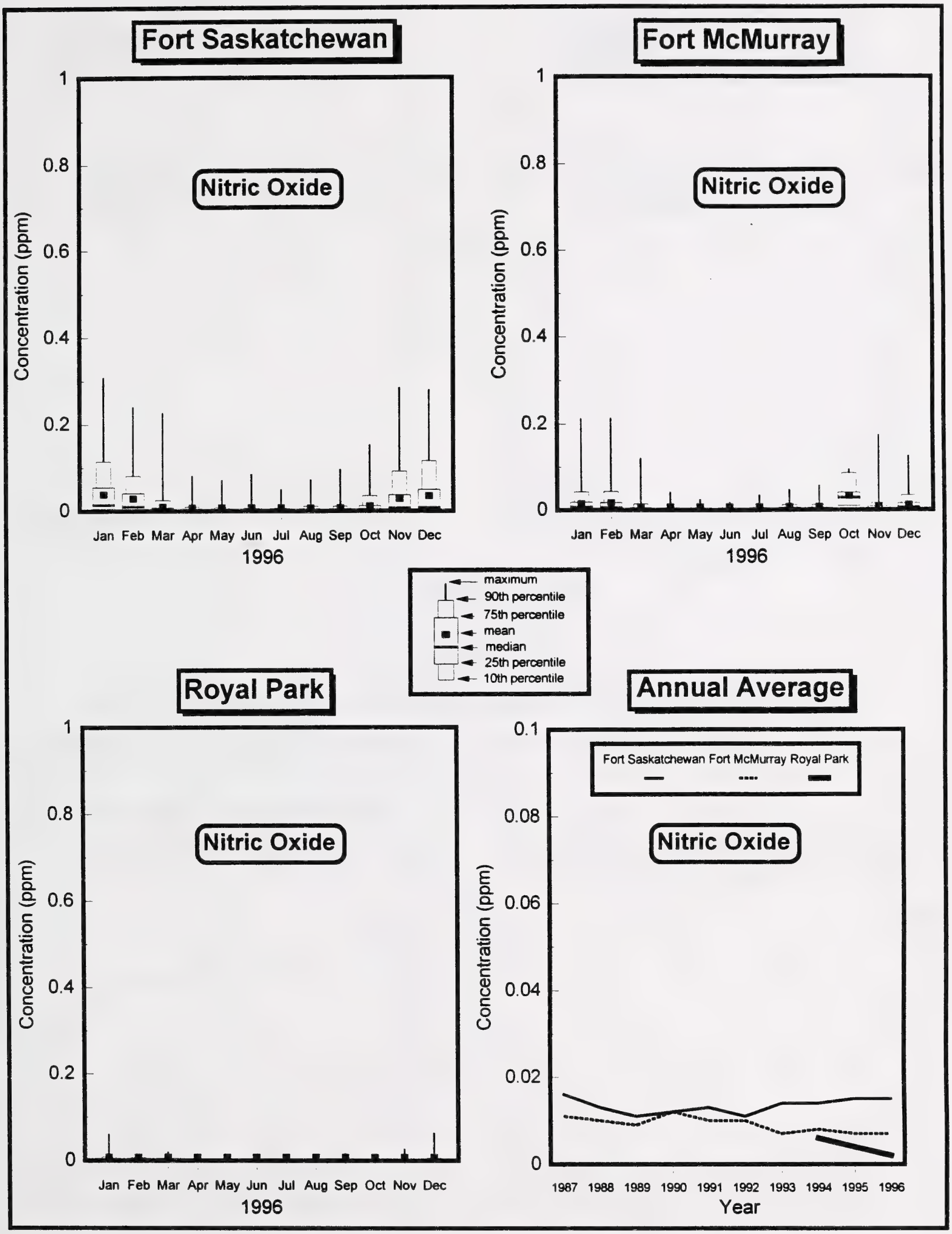


Figure 4-21 Frequency distribution of nitric oxide concentrations at Fort Saskatchewan, Fort McMurray and Royal Park.

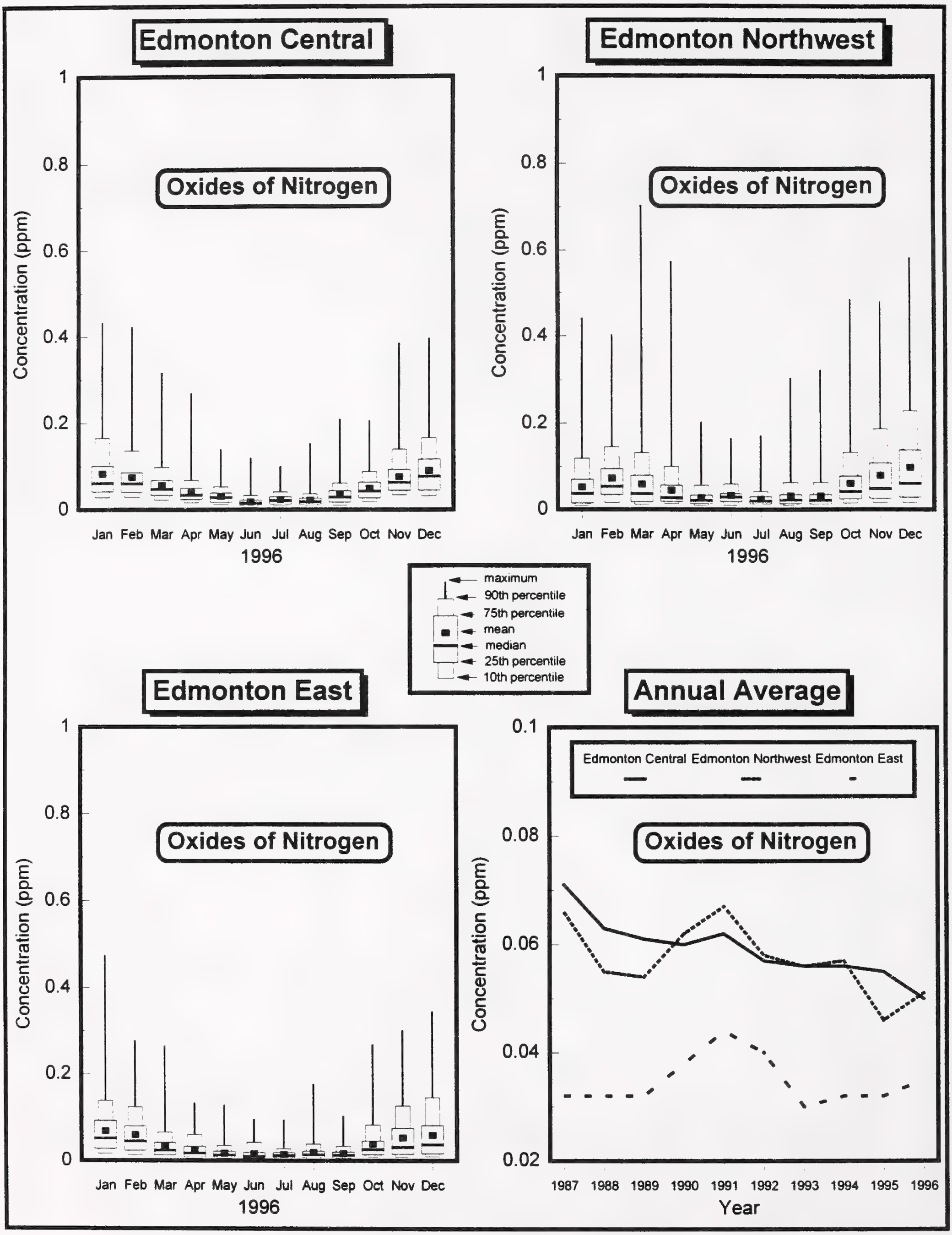


Figure 4-22 Frequency distribution of oxides of nitrogen concentrations at Edmonton.

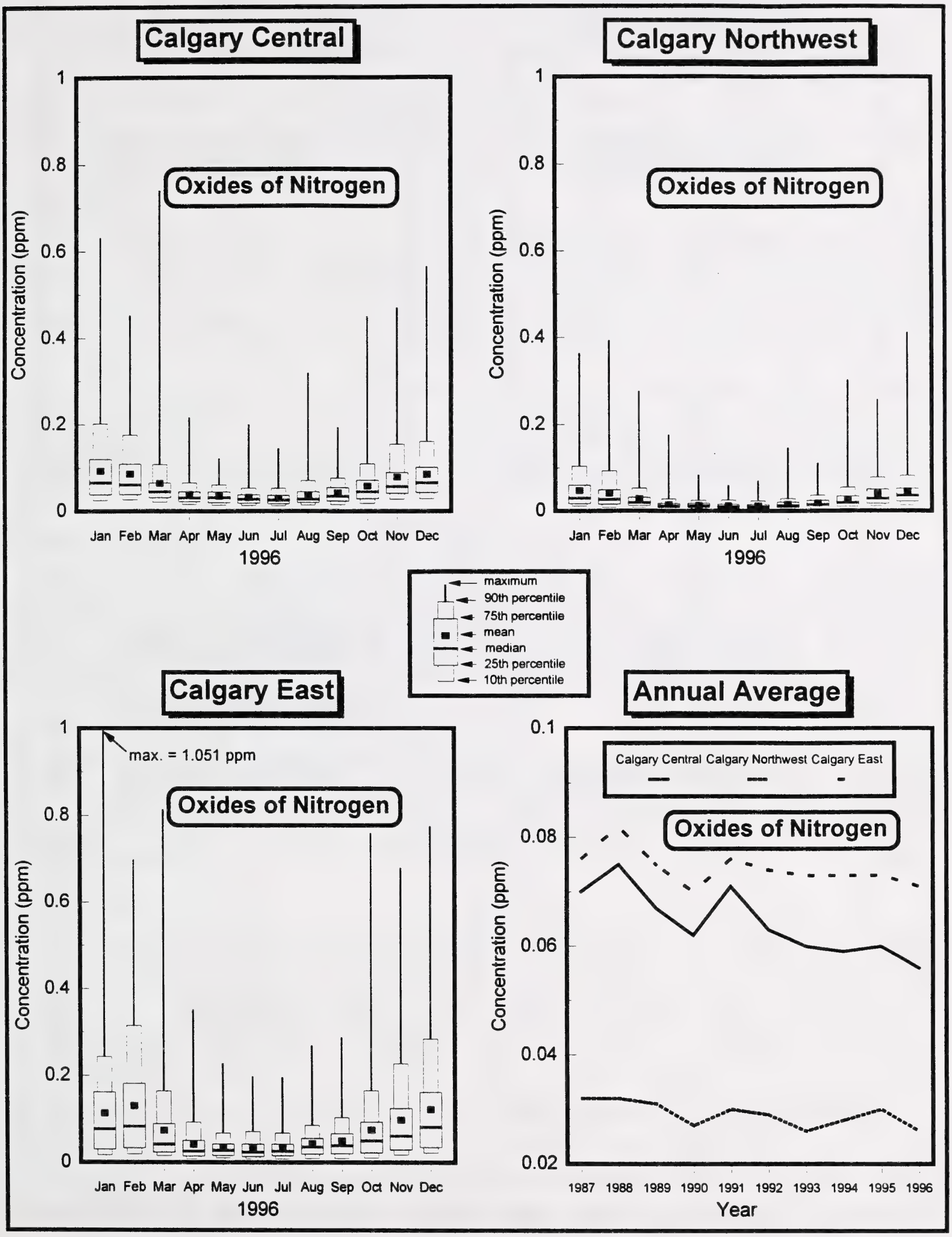


Figure 4-23 Frequency distribution of oxides of nitrogen concentrations at Calgary.

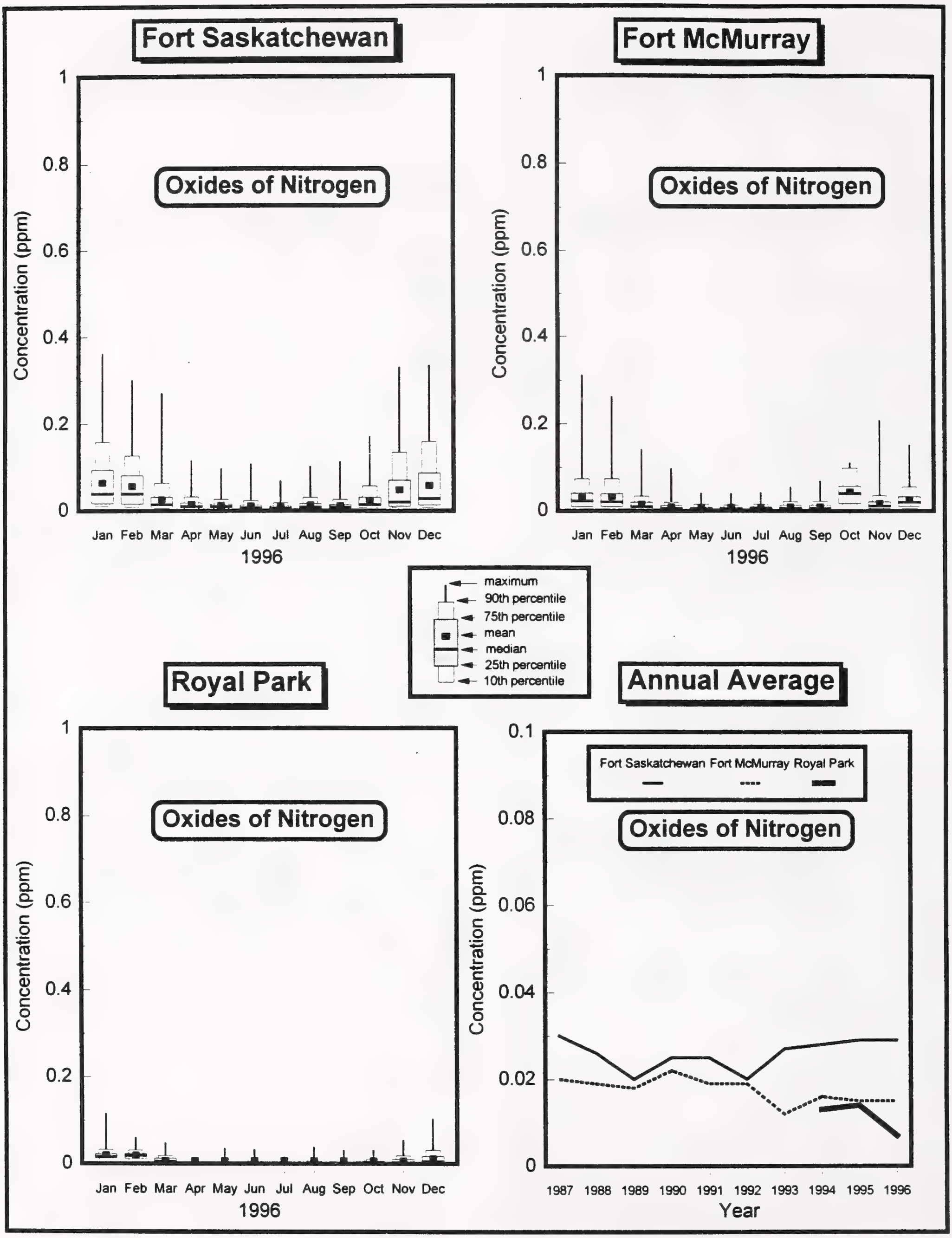


Figure 4-24 Frequency distribution of oxides of nitrogen concentrations at Fort Saskatchewan, Fort McMurray and Royal Park.

Maximum 1-hour average NO concentrations of 0.355, 0.585 and 0.391 ppm occurred at the Central, Northwest and East monitoring stations, respectively. Maximum 1-hour values were recorded in January at the Central and East stations, and March at the Northwest station. Maximum NO_X concentrations were also observed in January at the Central and East stations and March at the Northwest station. Peak 1-hour average NO_X concentrations were 0.434, 0.704 and 0.475 ppm at the Central, Northwest and East stations, respectively. Annual average NO_2, NO and NO_X concentrations show a significant downward trend at the Edmonton Central monitoring station.

➢ *Calgary*

Air quality guidelines for NO_2 were not exceeded at any Calgary monitoring stations in 1996. Maximum 1-hour average concentrations of 0.152 ppm, 0.089 ppm and 0.171 ppm were recorded at the Central, Northwest and East stations, respectively. These values were recorded in March at the Central and East stations, and in March and December at the Northwest station. A downward trend in NO_2 concentrations is evident at the Central monitoring station based on data from 1976 to 1996.

Peak 1-hour average NO concentrations of 0.637, 0.323 and 0.887 ppm occurred at the Central, Northwest and East monitoring stations in March, December and January, respectively. Maximum NO_X values of 0.741 ppm in March, 0.412 ppm in December and 1.051 ppm in January were observed at the Central, Northwest and East monitoring locations, respectively. Annual average NO_2 and NO_X concentrations also show a downward trend at the Calgary Central station.

➢ *Fort Saskatchewan*

Maximum 1-hour average NO_2, NO, and NO_X concentrations were 0.075, 0.309 and 0.363 ppm, respectively at the Fort Saskatchewan monitoring station. All three maximum values were recorded in January. The 1-hour, 24-hour and annual average guidelines for NO_2 were not exceeded in Fort Saskatchewan. The maximum 1-hour NO_2 concentration (0.075 ppm) was 36% of the guideline. Annual average concentrations do not show a trend at the Fort Saskatchewan station.

➢ *Fort McMurray*

The air quality guidelines for NO_2 were not exceeded at the Fort McMurray monitoring station in 1996. Peak 1-hour average values for NO_2, NO and NO_X were 0.098, 0.214 and 0.312 ppm, respectively. The peak values of NO_2 and NO_X were recorded in January, while the peak NO was recorded in January and February. A significant trend in oxides of nitrogen values is not apparent in Fort McMurray.

➢ *Royal Park*

The 1-hour, 24-hour and annual air quality guidelines for NO_2 were not exceeded at the Royal Park monitoring station in 1996. The maximum NO_2 concentration was 0.057 ppm which is 27% of the 1-hour guideline. NO and NO_X concentrations were substantially lower at the Royal Park station than at stations located in urban and small urban centres. Maximum 1-hour concentrations were 0.064 ppm for NO and 0.117 ppm for NO_X. These peak values were recorded in December and January, respectively.

4.8 OZONE (O_3)

4.8.1 Characteristics

O_3 is a colourless gas that is odourless at normal ambient concentrations. However, O_3 does have a characteristic sharp odour at concentrations higher than 1 ppm, such as those in the vicinity of photocopier machines, lightning storms, and electrical discharges associated with arcing electric motors.

Unlike many other pollutants, O_3 is not emitted into the atmosphere directly by man's activities, but is produced through the inter-reaction of atmospheric chemicals and energy in the form of light.

In the upper atmosphere, O_3 is generated naturally through the reaction of molecular oxygen with ultra-violet radiation from the sun. In the lower atmosphere, O_3 is formed through a complex set of photochemical reactions involving oxides of nitrogen (NO_X) and volatile organic compounds (VOCs) in the presence of ultra-violet radiation from the sun. The primary sources of NO_X are listed in Section 4.7. VOCs may originate from natural sources such as trees and vegetation or anthropogenic sources such as automobile exhaust, paints, inks, solvents, gasoline and various industrial processes (e.g. chemical and petrochemical plants). O_3 and O_3 precursors, such as NO_X and VOCs, may also be carried from upwind sources such as urban centres and industrial complexes. O_3 is also transported to ground-level from the O_3 rich upper troposphere through natural meteorological mixing processes. This process may lead to peaks in daily and monthly average ozone concentrations during the spring season.

O_3 concentrations tend to be lower in urban locations than rural locations in Alberta. Cities act as sinks, destroying O_3 that is formed in or near the city. In urban areas, NO emitted from motor vehicles reacts with O_3 to produce NO_2 and molecular oxygen. By contrast, in rural areas with less vehicles, naturally generated O_3 (produced by the reaction of sunlight with NO_X and natural hydrocarbons or transported from the upper atmosphere) is less prone to destruction by NO.

4.8.2 Method of Monitoring

O_3 is continuously monitored by either the chemiluminescence or ultra-violet photometry process. The chemiluminescent process involves the reacting of an air sample with ethylene. The reaction of ethylene and O_3 produces light. The intensity of the light produced is proportional to the O_3 concentration. The ultra-violet photometry process uses a mercury vapour lamp as a source of ultra-violet radiation. This method determines the O_3 concentration by the amount of ultra-violet radiation that is absorbed by the O_3 in the sample.

4.8.3 Guidelines

The guidelines for the maximum permissible concentration of O_3 are based on the prevention of adverse effects on human health and vegetation. Alberta has high natural levels of O_3 and frequently, especially in rural locations, exceeds the 24-hour guideline (Angle and Sandhu 1986). The air quality guidelines for O_3 are currently under review by a federal-provincial committee. The ambient air quality guidelines for O_3 in Alberta are:

- 0.082 ppm as a 1-hour average concentration; and
- 0.025 ppm as a 24-hour average concentration.

4.8.4 Results

Ambient concentrations of O_3 were monitored at all three Edmonton and Calgary air monitoring stations as well as Fort Saskatchewan, Fort McMurray, Royal Park and Springbank Airport. A frequency distribution of monthly O_3 concentrations and annual average O_3 concentrations for these locations is presented in Figures 4-25 to 4-28.

Annual average O_3 concentrations ranged from 0.014 ppm at the Calgary Central monitoring station to 0.032 ppm at the Springbank Airport monitoring station. Relatively high annual average values of 0.030 ppm and 0.025 ppm were also recorded at the Royal Park and Fort Saskatchewan stations, respectively. Lower annual average O_3 concentrations were generally recorded at monitoring stations that are located in areas with high traffic density. This is because higher concentrations of NO from motor vehicle emissions will act as a mechanism for O_3 destruction.

Average O_3 concentrations reached a maximum during the spring and summer months at most monitoring stations. During the spring, higher daily and monthly average ozone values are associated with O_3 transported to ground-level from the upper troposphere and O_3 produced through the reaction of volatile organic compounds and oxides of nitrogen in the presence of sunlight. In the summer months, high O_3 production is likely due to a peak in incoming solar radiation combined with stagnant meteorological conditions which may cause reactive pollutants to remain in the region for a prolonged period of time. Transport of rural background O_3 to urban locations is likely the most common cause of high O_3 in Edmonton and Calgary.

A noticeable trend towards higher O_3 concentrations in the afternoon was evident at all monitoring locations. O_3 concentrations tended to increase to a maximum in late afternoon and then drop off to a minimum in the early morning hours. This afternoon peak in O_3 generally occurs after the daily maximum in solar radiation and also corresponds with the peak in atmospheric instability.

➢ *Edmonton*

Exceedances of the 1-hour guideline for ozone were reported two times at the Edmonton Northwest monitoring station in 1996. These exceedances occurred on August 30 from 1 p.m. to 3 p.m. during hot weather conditions. Winds were from the east-southeast prior to the exceedances. High 1-hour ozone values may have been caused by the combination of ozone generated by natural processes with the possible influence of ozone precursors (oxides of nitrogen and volatile organic compounds) emitted in the Edmonton area. The 1-hour guideline was not exceeded at the Edmonton Central or the Edmonton East station. Peak 1-hour average O_3 concentrations of 0.068, 0.084 and 0.076 ppm were observed at the Central, Northwest and East monitoring stations, respectively. These maximum values were recorded in August at all three stations.

The 24-hour average guideline for O_3 was exceeded 38 times at both the Edmonton Central and Edmonton Northwest monitoring stations, and 119 times at the East station. These exceedances were most common in the months of May and June. Exceedances of the 24-hour guideline for ozone are primarily due to ozone generated by natural processes. These processes include the transport of ozone from the upper atmosphere to ground level and the reaction of hydrocarbons (from vegetation) and oxides of nitrogen in the presence of sunlight. Because of these natural processes, ozone in the background atmosphere will frequently exceed the 24-hour guideline in the spring and summer seasons. The 24-hour guideline for ozone is currently under review by a federal-provincial committee.

A slight increase in annual average O_3 values is detectable at the Central air quality station. This trend is likely due to less NO being emitted by automobiles in downtown Edmonton.

➢ *Calgary*

The 1-hour guideline for O_3 was not exceeded at any Calgary monitoring stations in 1996. Peak 1-hour average O_3 concentrations of 0.057, 0.077 and 0.063 ppm were observed at the Central, Northwest and East monitoring locations, respectively. These maximum values were recorded in June at the Central and East stations, and in August at the Northwest station.

The frequency of exceedances of the 24-hour guideline for O_3 ranged from 23 at the Central station to 63 at the East station and 144 at the Northwest station. The greatest frequency of exceedances of this guideline occurred in the spring and summer months. These exceedances were caused by the import of background, naturally generated O_3 into the city. A small upward trend in annual average O_3 concentrations is indicated at the Calgary Central monitoring station. This upward trend is likely due to lower emissions of NO from automobiles in downtown Calgary.

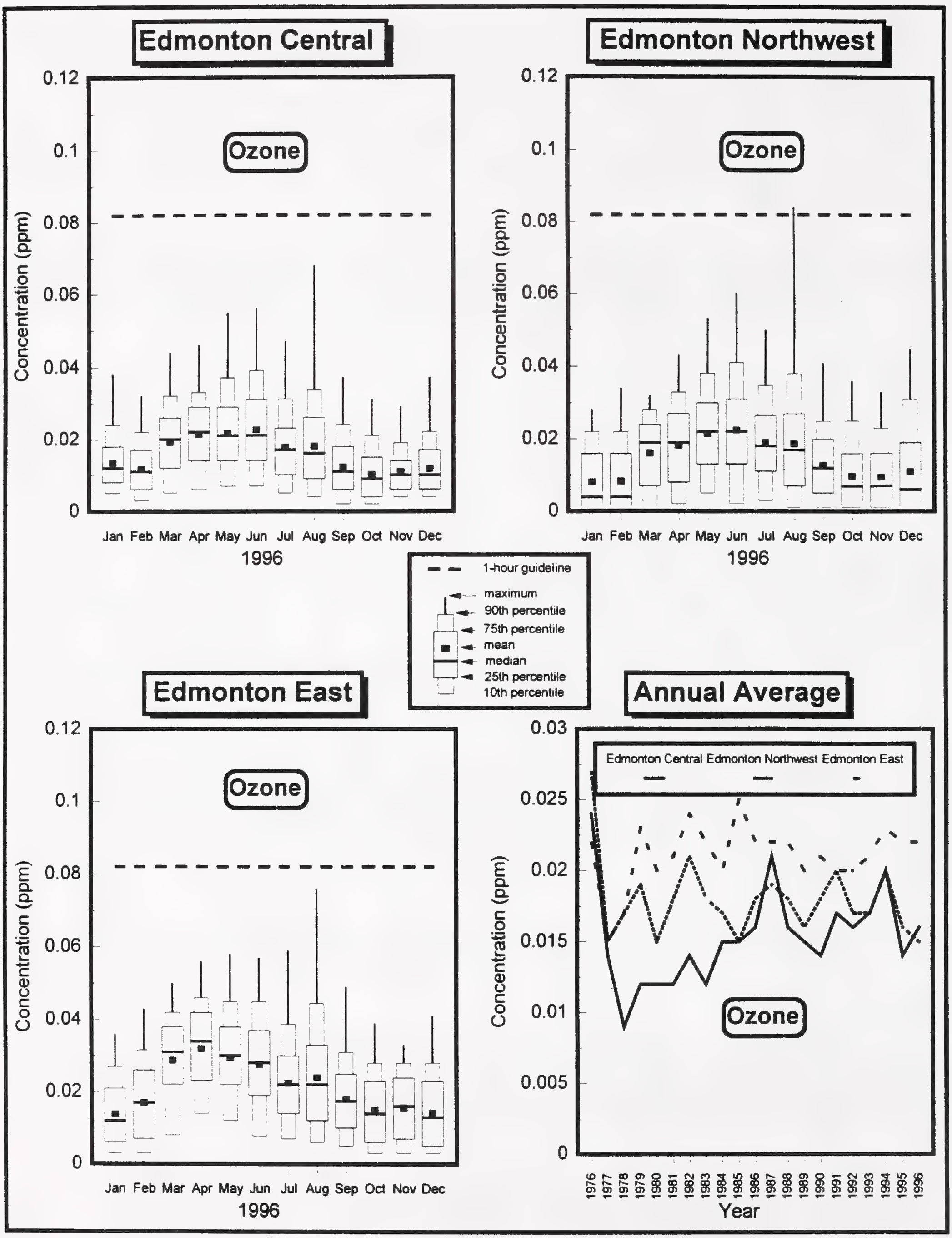


Figure 4-25 Frequency distribution of ozone concentrations at Edmonton.

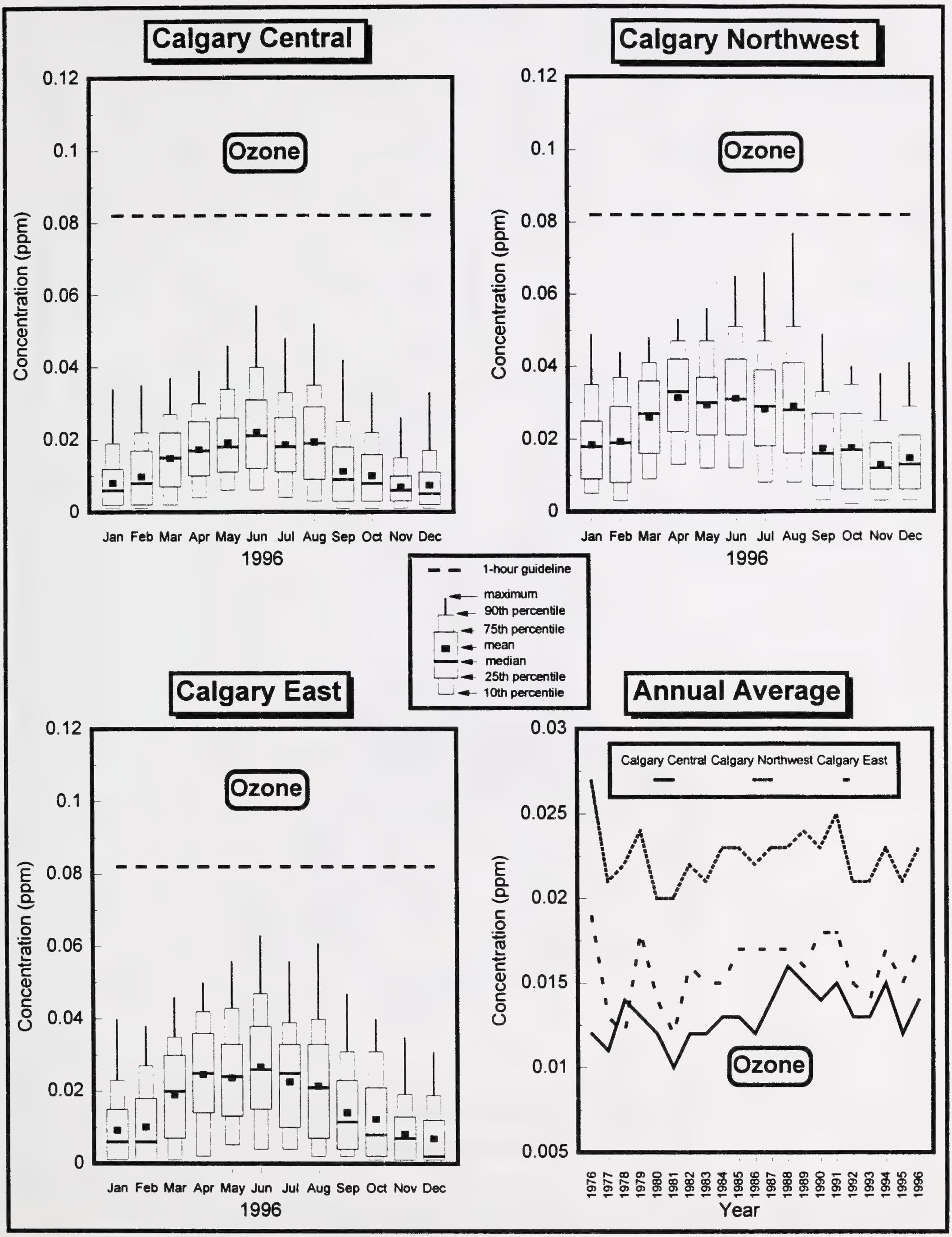


Figure 4-26 Frequency distribution of ozone concentrations at Calgary.

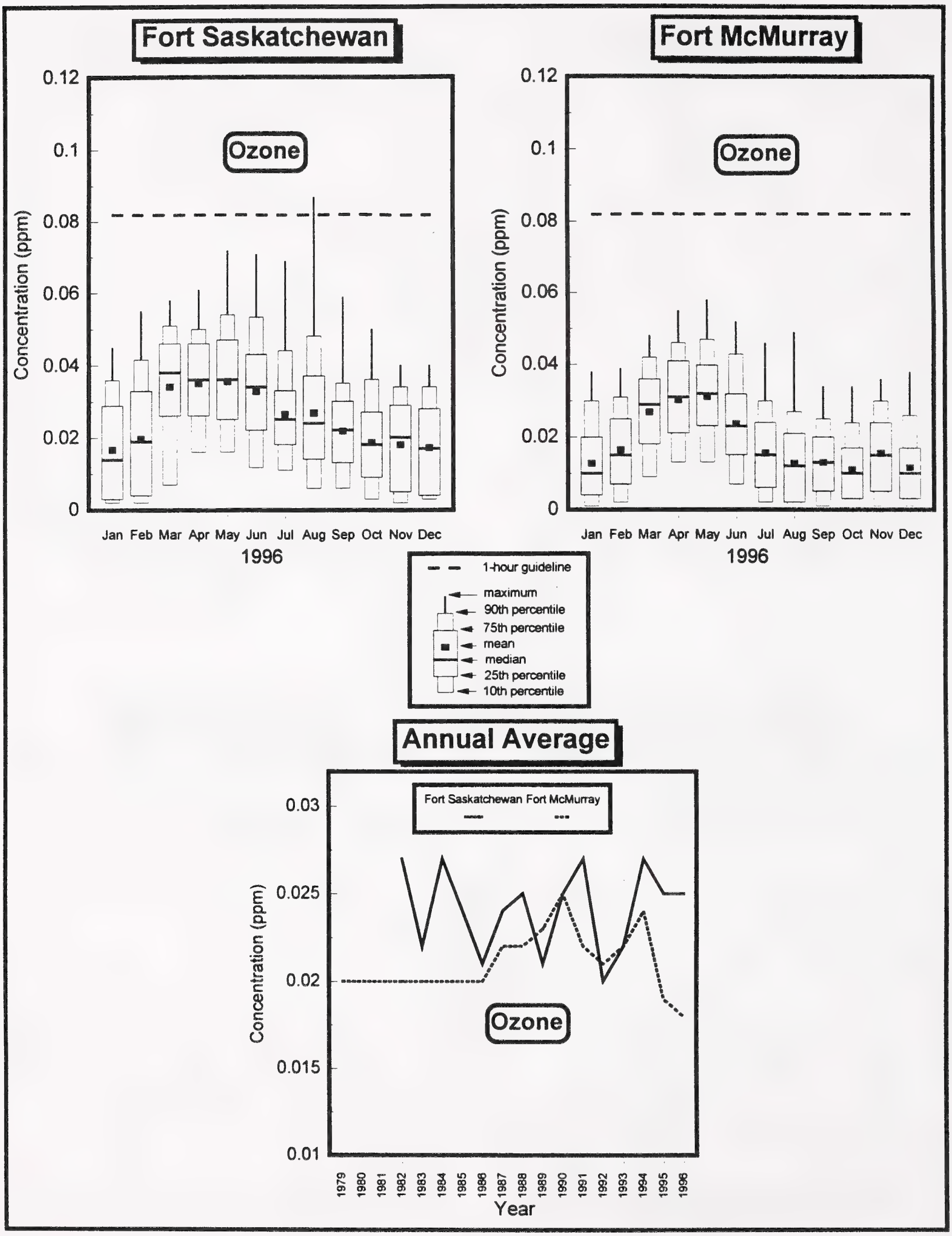
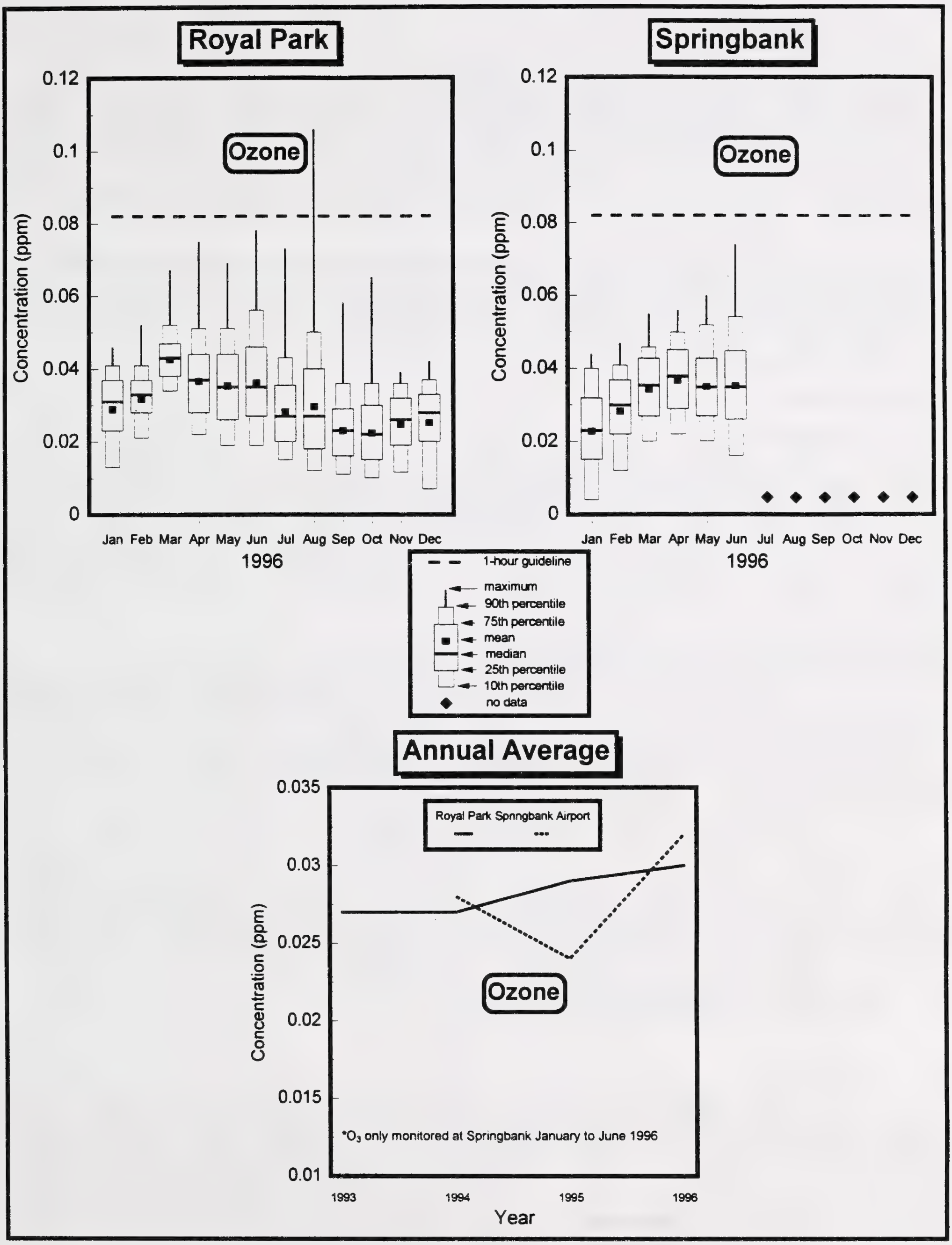


Figure 4-27 Frequency distribution of ozone concentrations at Fort Saskatchewan and Fort McMurray.



*O_3 only monitored at Springbank January to June 1996

Figure 4-28 **Frequency distribution of ozone concentrations at Royal Park and Springbank.**

- ***Fort Saskatchewan***

  The 1-hour average guideline for O_3 was exceeded 3 times at the Fort Saskatchewan station in 1996. These ozone episodes occurred for one hour each in the afternoon on August 9, 29 and 30 during hot weather conditions (temperatures greater than 25°C). Winds were from the west-southwest prior to the exceedances on August 9 and 29, and from the southeast prior to the exceedance on August 30. These exceedances were likely caused by ozone generated by natural processes with the incremental contribution of ozone generated by human sources (oxides of nitrogen and volatile organic compound emissions from vehicles and industry) in the Edmonton and Fort Saskatchewan area.

  The 24-hour guideline was exceeded 181 times, over the year, with the majority of exceedances in May and June. Again, the source of high 24-hour ozone concentrations was naturally generated O_3. No significant trend in annual average O_3 concentrations is noted at the Fort Saskatchewan monitoring unit.

- ***Fort McMurray***

  The 1-hour guideline for O_3 was not exceeded at the Fort McMurray monitoring station in 1996. A maximum 1-hour average concentration of 0.058 ppm was recorded in May at the Fort McMurray station. As with other monitoring locations, the 24-hour guideline for O_3 was exceeded frequently (92 times). The 24-hour guideline was exceeded most frequently from March to June. There is a substantial decrease in the frequency of exceedances of the 24-hour guideline in the summer, autumn and winter months. The majority of O_3 generated in the Fort McMurray area originates from natural sources. A significant trend in annual average O_3 concentrations is not evident at the Fort McMurray monitoring station based on 18 years of data.

- ***Royal Park and Springbank Airport***

  The 1-hour guideline for O_3 was exceeded 3 times in 1996 at the Royal Park monitoring station. All three of these exceedances occurred on the afternoon of August 29, with a maximum 1-hour reading of 0.106 ppm. These exceedances were recorded during hot weather conditions and were primarily due to background ozone. Winds on the afternoon of August 29 were from the north-northeast from 25 to 35 km/h.

  At the Springbank Airport monitoring station in 1996, the maximum 1-hour value was 0.074 ppm, recorded in June. This maximum value is 90% of the 1-hour guideline. (Air quality was monitored from January to June, 1996 at the Springbank monitoring station.) The 24-hour guideline was exceeded 252 times at the Royal Park station and 137 times at the Springbank Airport monitoring station. The source of these exceedances was O_3 generated by natural processes.

4.9 INHALABLE PARTICULATES (PM_{10})

4.9.1 Characteristics

Inhalable particulates or PM_{10}, refers to particles that have an aerodynamic diameter of less than 10 micrometres (μm) and are suspended in the air for an indefinite period of time. In general, particles smaller than 1 μm in diameter exist in the atmosphere primarily as by-products of condensation and combustion. Inhalable particulates between 1 and 10 μm in diameter usually include soil, process dusts, and combustion products from industries. Particles larger than 10 μm in diameter result from mechanical processes such as wind erosion, grinding, spraying and vehicular activity.

Since particles enter the body through the respiratory system, most of their immediate effects are on this system. The factor which determines the depth of penetration into the respiratory system is the particle size. Larger particles tend to be deposited in the upper respiratory tract, such as the nose and throat, while smaller particles travel deeper into the lungs. The toxicity of the particles, however, varies with the chemical composition. Particles that can be inhaled are typically less than 10 µm in diameter.

Inhalable particles may result from a variety of natural and anthropogenic sources. These sources include vehicle exhaust emissions, soil, road dust, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces), and industrial emission sources.

4.9.2 Method of Monitoring

Inhalable particulates are monitored on a continuous basis using the Tapered Element Oscillating Microbalance (TEOM). The TEOM draws an air sample through an inlet stream that aerodynamically separates particles of a specified diameter (e.g. 10 µm). The air sample then passes through a filter that is attached to a tapered element in the mass transducer. This tapered element vibrates at its natural frequency. As particles are deposited onto the filter the oscillating frequency changes in proportion to the amount of mass deposited.

4.9.3 Guidelines

At the present time, Alberta does not have a guideline for inhalable particulates. However, guidelines for particles less than 10 µm (PM_{10}) and less than 2.5 ($PM_{2.5}$) µm in diameter are currently being developed at the national level.

4.9.4 Results

In 1996, inhalable particulates were monitored continuously at the Edmonton Northwest and Calgary Central monitoring stations. The frequency distribution of inhalable particulate data at these stations is presented in Figure 4-29.

A diurnal variation in PM_{10} concentrations was evident at the Edmonton Northwest and Calgary Central stations. Values tended to be higher during and after the morning and afternoon rush hours. This diurnal trend is especially noticeable in the fall, winter and spring seasons. Higher concentrations at these times can be attributed directly to vehicle exhaust emissions as well as traffic movement.

- ***Edmonton***

  The annual average PM_{10} concentration at the Edmonton Northwest station was 15.9 µg/m^3. The maximum 1-hour average concentration was 302 µg/m^3 which was measured in March. Higher concentrations were generally recorded in the spring and summer. Higher values in the spring months were likely related to residual sand and dust from winter road sanding. Higher PM_{10} values in the late summer and fall months were likely due to vehicle exhaust emissions.

- ***Calgary***

  The average PM_{10} concentration for the Calgary Central station was 13.1 µg/m^3. The maximum hourly value (169 µg/m^3), and the maximum monthly average value (18.9 µg/m^3) were recorded in February. Higher PM_{10} concentrations in the winter were likely caused by stable weather conditions which inhibit dispersion of vehicle exhaust emissions.

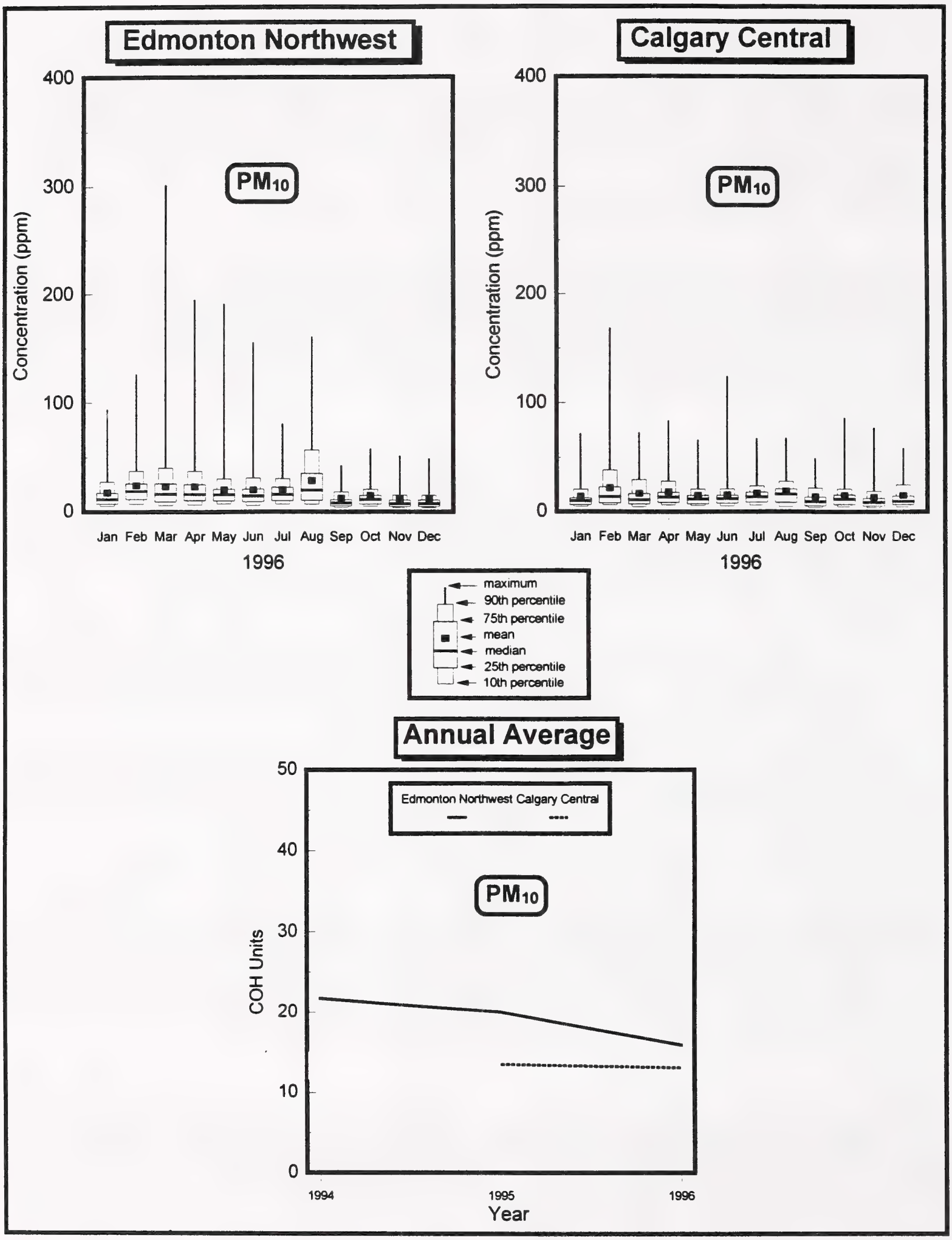


Figure 4-29 Frequency distribution of PM10 concentrations at Edmonton and Calgary.

4.10 SULPHUR DIOXIDE (SO_2)

4.10.1 Characteristics

SO_2 is a heavy, colourless gas with a pungent odour and is designated as a major atmospheric pollutant on a global basis. Processes such as the combustion of fossil fuels, smelting and roasting of sulphur-containing ores, kraft and sulphite wood pulping, and sour gas processing produce most of the man-made atmospheric SO_2.

In Alberta, about 42% of the SO_2 emissions are contributed by natural gas processing plants; oil sands plants and coal-fired power plants contribute about 26% and 18%, respectively. The remaining 16% of SO_2 is emitted from sources such as oil refineries, crude oil production, transportation, gas plant flares, pulp and paper mills and fertilizer plants (Deslauriers, 1995).

4.10.2 Method of Monitoring

SO_2 is monitored continuously by pulsed fluorescence. In this method, air is drawn through a sample chamber where it is irradiated with pulses of ultra-violet light. Any SO_2 in the sample is excited to a higher energy level and upon returning to its original state, light or fluorescence is released. The amount of fluorescence measured is proportional to the SO_2 concentration.

4.10.3 Guidelines

The guidelines for the maximum permissible concentration of SO_2 are based on preventing damage to vegetation. At these levels, no adverse health effects have been documented. Alberta has adopted Environment Canada's maximum desirable ambient levels for SO_2:

- 0.17 ppm as a 1-hour average concentration;
- 0.06 ppm as a 24-hour average concentration; and
- 0.01 ppm as an annual arithmetic concentration.

4.10.4 Results

SO_2 was monitored on a continuous basis at the Edmonton East, Calgary East, Fort Saskatchewan, Fort McMurray and Fort MacKay monitoring stations. Figures 4-30 and 4-31 show monthly frequency distributions and annual averages of SO_2 at these monitoring locations.

Annual average SO_2 concentrations ranged from 0.002 ppm at Fort Saskatchewan and Fort McMurray to 0.004 ppm at the Calgary East station. Annual average values were 0.003 ppm at the Fort MacKay and Edmonton East monitoring stations. These values are substantially lower than the annual average guideline of 0.010 ppm for SO_2. At the Edmonton, Calgary and Fort Saskatchewan stations, average SO_2 concentrations tended to be higher in the winter months. At the Fort McMurray and Fort MacKay stations, the highest concentrations were usually observed in the spring season. A well-defined diurnal trend in SO_2 is not evident. Annual average SO_2 concentrations are not high enough to resolve a significant trend at any of the monitoring locations.

➢ Edmonton

Exceedances of air quality guidelines for SO_2 were not recorded at the Edmonton East station in 1996. The maximum 1-hour average SO_2 concentration reported at the East station was 0.052 ppm. This value was reported in March and is 31% of the 1-hour guideline for SO_2. The maximum 24-hour concentration was 0.010 ppm which is 17% of the guideline.

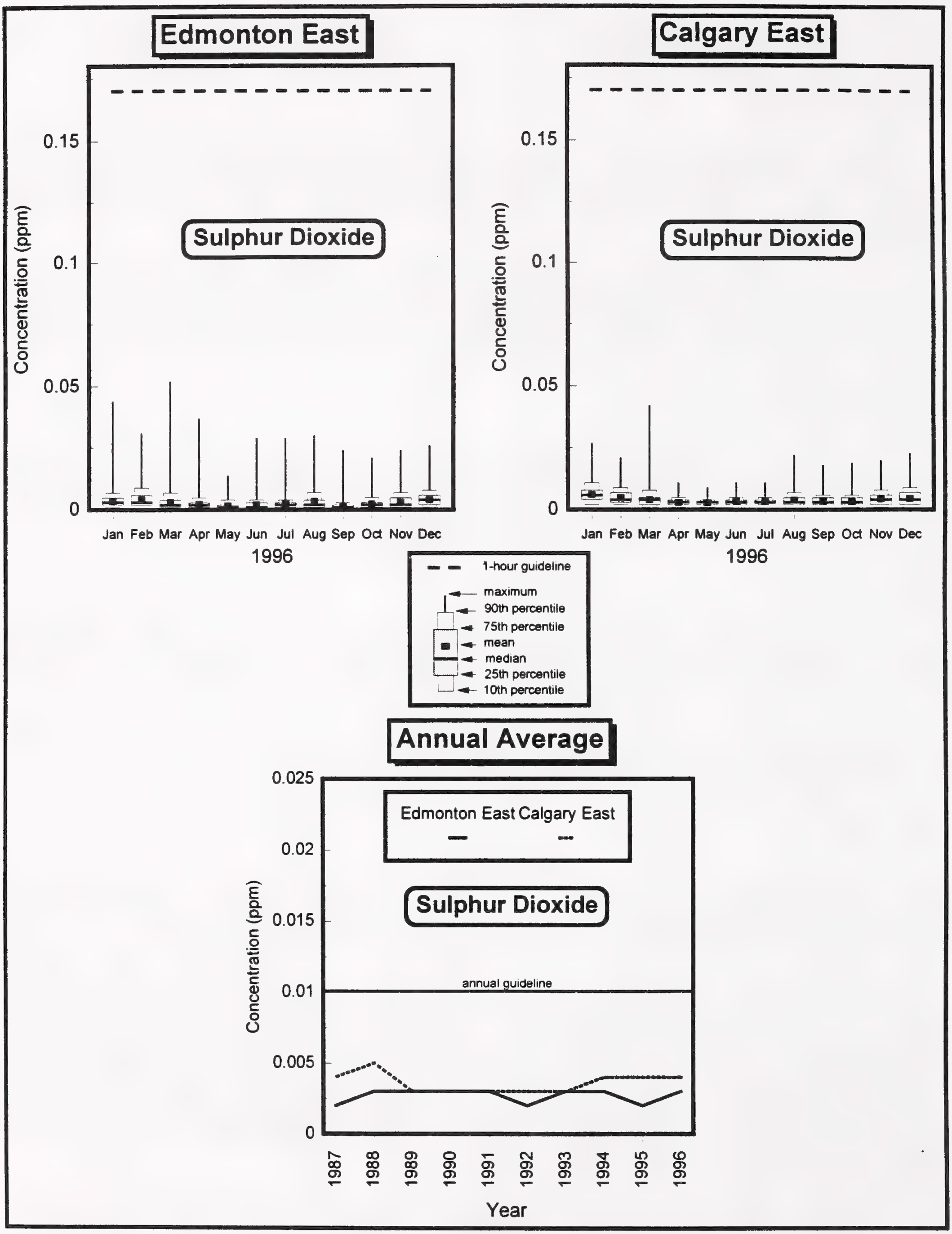


Figure 4-30 Frequency distribution of sulphur dioxide concentrations at Edmonton and Calgary.

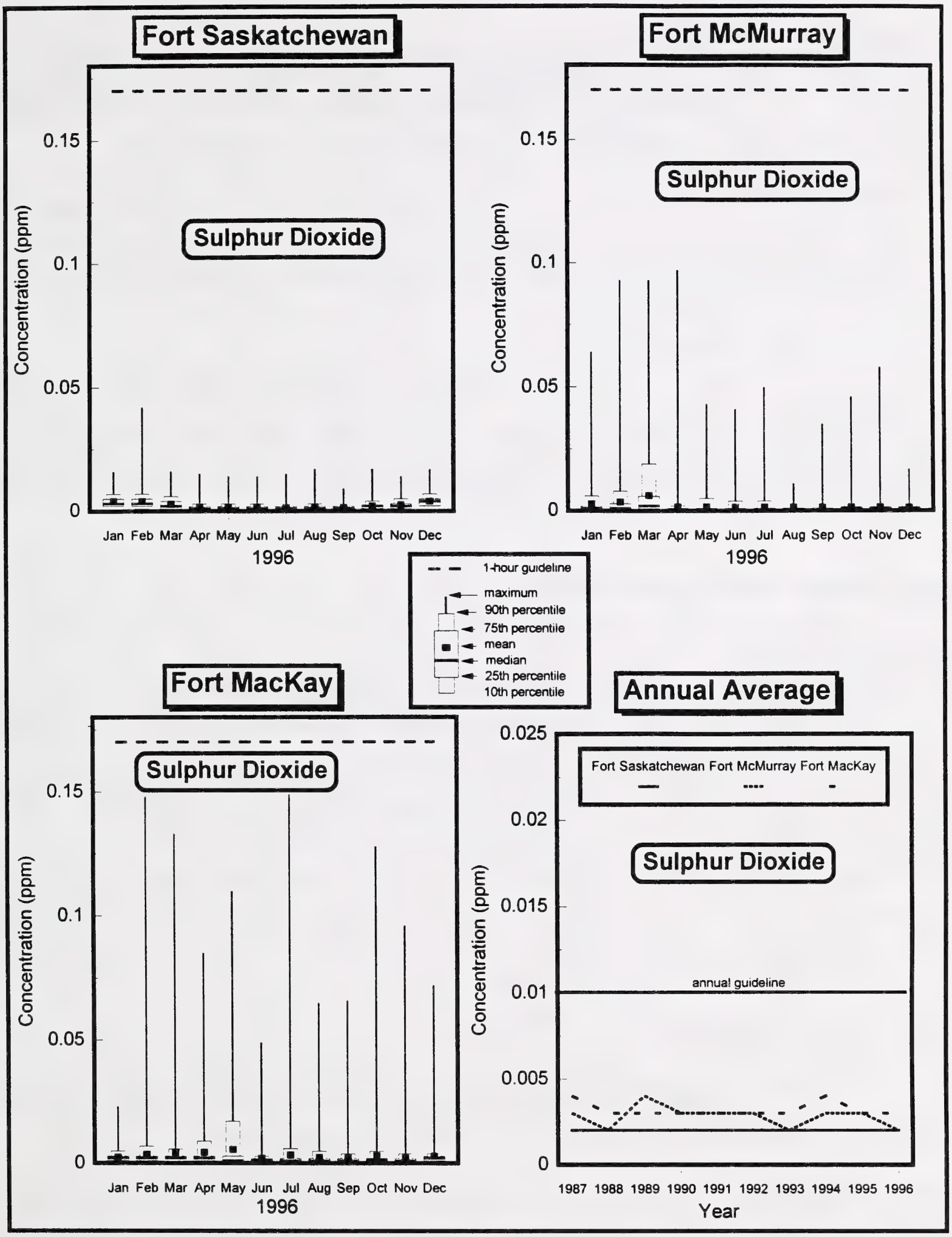


Figure 4-31 Frequency distribution of sulphur dioxide concentrations at Fort Saskatchewan, Fort McMurray and Fort MacKay.

- ***Calgary***

  The 1- and 24-hour guidelines for SO_2 were not exceeded at the Calgary East monitoring location. The maximum observed 1-hour average SO_2 concentration at the Calgary East monitoring station was 0.042 ppm. This maximum value was also recorded in March and is 25% of the 1-hour guideline. The maximum 24-hour concentration (0.012 ppm) was 20% of the 24-hour guideline.

- ***Fort Saskatchewan***

  Guidelines for SO_2 were not exceeded at the Fort Saskatchewan monitoring unit in 1996. The maximum 1-hour average SO_2 concentration was 0.042 ppm. This maximum value was recorded in February and is 25% of the 1-hour guideline for SO_2 of 0.170 ppm. The peak 24-hour average of 0.010 ppm was 17% of the guideline.

- ***Fort McMurray and Fort MacKay***

  The air quality guidelines for SO_2 were not exceeded at the Fort McMurray or the Fort MacKay monitoring stations in 1996. The maximum 1-hour concentration was 0.097 ppm at Fort McMurray and 0.149 ppm at Fort MacKay. These values are 57% and 88% of the 1-hour guideline, respectively. The maximum 24-hour average concentrations of 0.021 ppm at Fort McMurray and 0.022 ppm at Fort MacKay were 35% and 37% of the 24-hour guideline for SO_2, respectively. Major sources of SO_2 at these locations are the oilsands plants located near the communities.

4.11 TOTAL HYDROCARBONS (THC)

4.11.1 Characteristics

The term "total hydrocarbons" refers to the combined concentration of two broad categories of organic compounds: reactive and non-reactive hydrocarbons. The non-reactive component is primarily methane, a colourless, odourless gas. The reactive component is essentially organic compounds other than methane that are usually present in much lower concentrations. Reactive hydrocarbons are especially important because they will react with oxides of nitrogen in the presence of sunlight to increase the formation of ozone.

Natural sources of hydrocarbons include trees and other vegetation, and the decay of animal and plant material. The primary man-made sources are motor vehicles, gasoline marketing tanks and storage tanks. Smaller amounts of hydrocarbons are emitted by sources such as the petroleum and chemical industries, dry-cleaning, fireplaces, natural gas combustion and aircraft traffic. Motor vehicle emissions of hydrocarbons are the result of incomplete combustion.

4.11.2 Method of Monitoring

Hydrocarbons are monitored continuously by a hydrogen flame ionization detector. When burned, carbon-hydrogen bonds break creating ions that conduct an electric current. This current is then measured by an electrometer to give a signal proportional to the number of ions.

4.11.3 Guidelines

Alberta does not have ambient air quality guidelines for hydrocarbons. Normal background THC concentrations are between 1.5 and 2.0 ppm.

4.11.4 Results

Hydrocarbons were monitored at all Edmonton, Calgary, Fort Saskatchewan, Fort McMurray and Fort MacKay air quality stations in 1996. Frequency distributions of these values are illustrated in Figures 4-32 to 4-34. These figures also show annual average THC concentrations.

Annual average THC concentrations ranged from 1.9 ppm at Fort MacKay to 2.4 ppm at the Edmonton East station. The highest annual average THC concentrations were recorded at the stations located close to major traffic arteries or industrial sources.

A distinct seasonal trend in hydrocarbon concentrations is evident at monitoring stations located close to major traffic arteries (Edmonton Central and Northwest, Calgary Central and East) based on data collected in 1996. Higher values are generally observed in the fall, winter and early spring months at these stations. At these urban locations, the predominant source of reactive hydrocarbons was automobile emissions, which are usually greater in the cold seasons. Industrial sources contributed to hydrocarbon readings at the Edmonton East location.

Significant diurnal trends of THC were also noted at monitoring stations located close to major traffic arteries. Diurnal trends were especially evident during the winter months at the Edmonton Central, Edmonton Northwest, Calgary Central, Calgary East and Fort Saskatchewan monitoring stations. Maximum THC concentrations generally occurred during the morning and afternoon rush hours.

➢ Edmonton

Maximum 1-hour average THC concentrations ranged from 4.7 ppm at the Central station to 18.3 ppm at the East monitoring station. These peak values occurred in January and March, respectively. A concentration of 11.0 ppm was also recorded at the East monitoring station in January. Relatively high THC concentrations observed in this industrial region of Edmonton were likely due to fugitive emissions from petrochemical storage and transport tanks. Based on 21 years of data, a small downward trend is noticeable at the Northwest station.

➢ Calgary

Maximum 1-hour THC concentrations were 5.2 ppm at the Central station, 3.6 ppm at the Northwest station and 5.6 ppm at the East station. These peak values were recorded in March, December, and February at the Central, Northwest and East monitoring stations, respectively. Based on 21 years of data, a very small upward trend in THC concentrations is evident at the Northwest and East monitoring stations.

➢ Fort Saskatchewan

The maximum 1-hour average THC concentration observed at the Fort Saskatchewan monitoring unit was 5.8 ppm. This maximum value was recorded in March. The sources of hydrocarbons in the Fort Saskatchewan region are vehicle emissions and emissions from local industrial facilities. Based on 14 years of data, an increase in annual average THC concentrations is evident in Fort Saskatchewan. However, the station was moved several times during this monitoring period.

➢ Fort McMurray and Fort MacKay

Maximum 1-hour average THC concentrations of 3.8 and 3.9 ppm were measured, respectively, at Fort McMurray and Fort MacKay. These values were recorded in January and December at the Fort McMurray and the Fort MacKay monitoring stations, respectively. A slight upward trend in THC concentrations is evident at the Fort McMurray station.

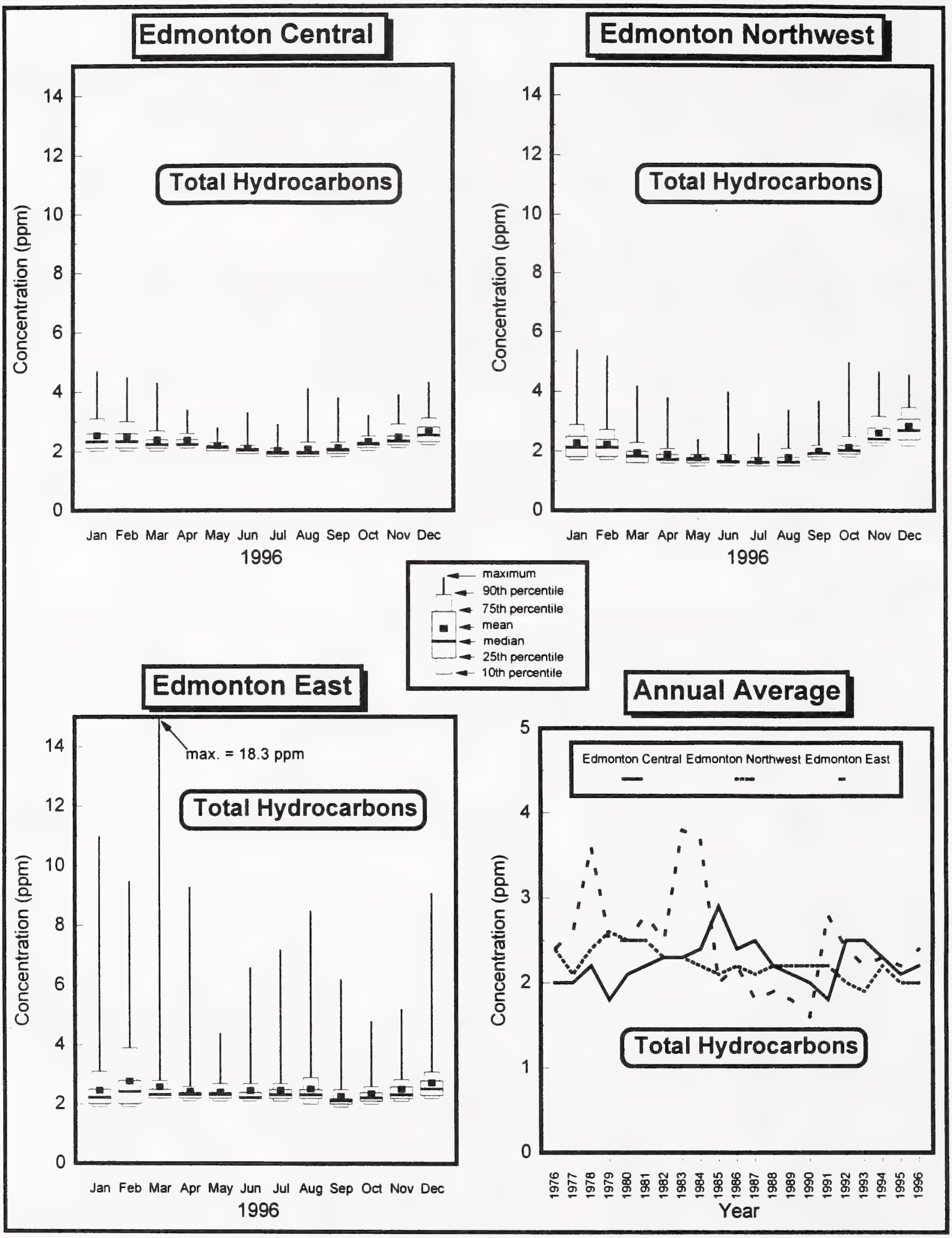


Figure 4-32 Frequency distribution of total hydrocarbon concentrations at Edmonton.

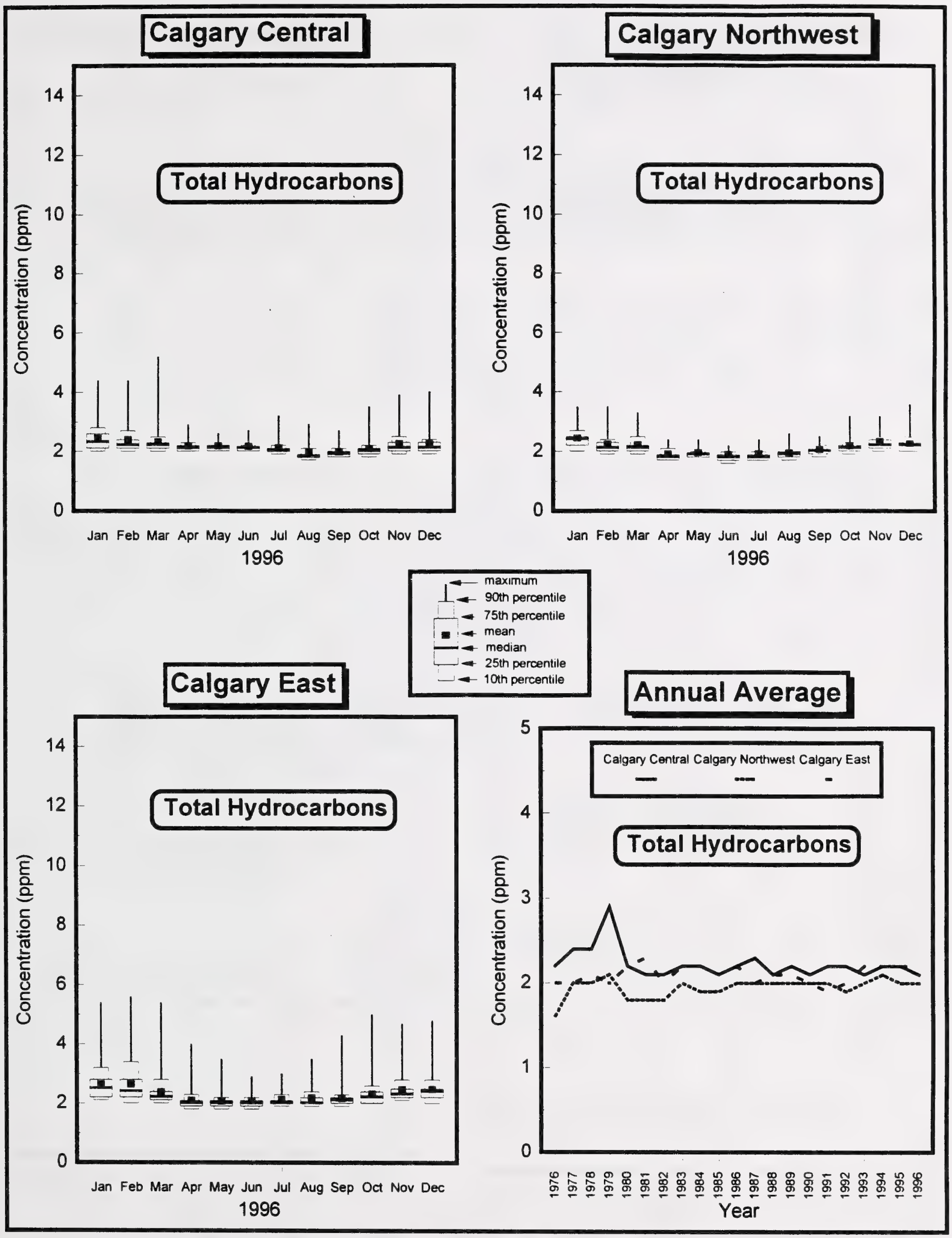


Figure 4-33 Frequency distribution of total hydrocarbon concentrations at Calgary.

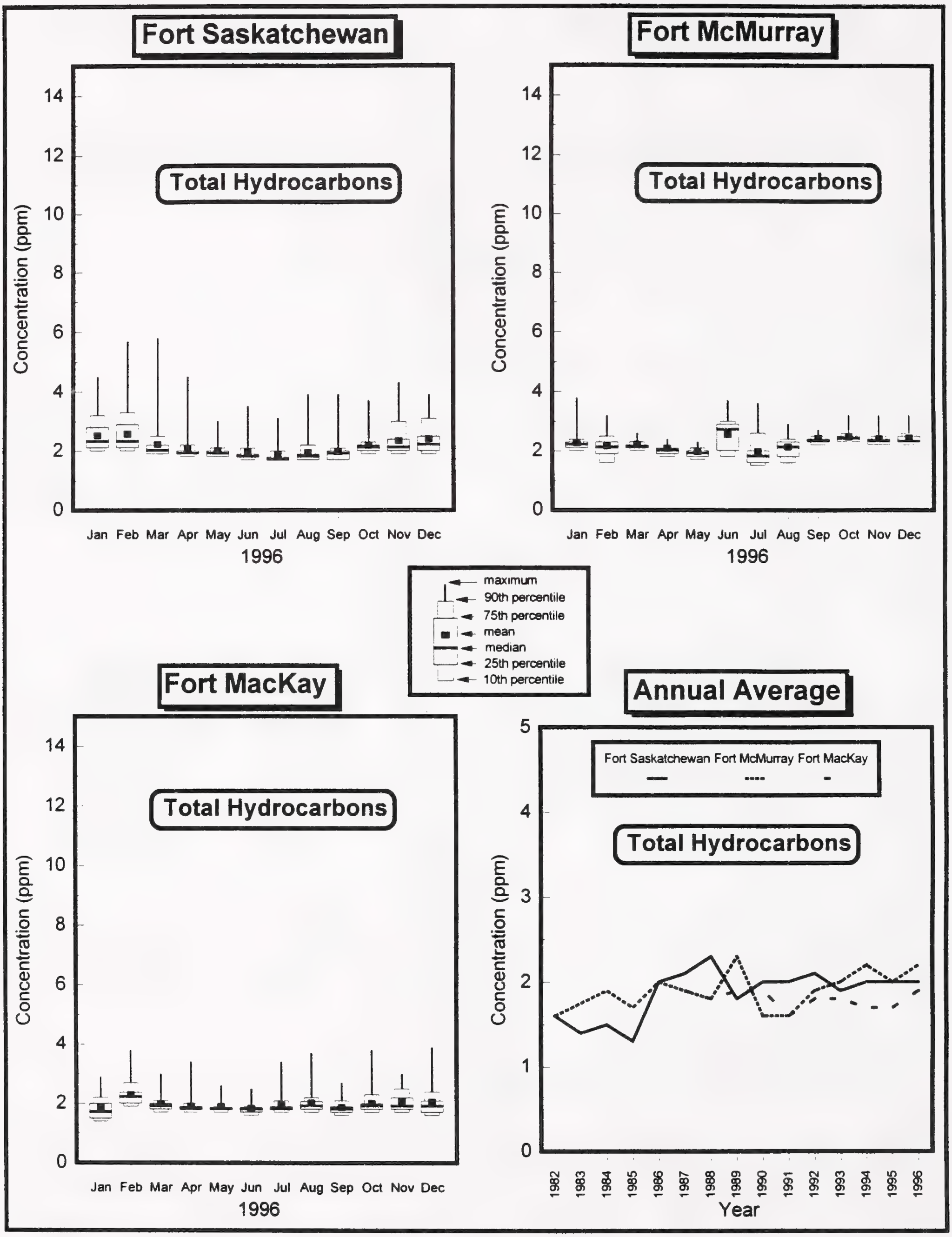


Figure 4-34 Frequency distribution of total hydrocarbon concentrations at Fort Saskatchewan, Fort McMurray and Fort MacKay.

4.12 AMMONIA (NH_3)

4.12.1 Characteristics

NH_3 is a colourless gas with the well-known pungent odour found in household cleaners. NH_3 occupies a unique position as it is generally considered to be a desirable chemical, particularly in fertilizers, and not as a potential environmental pollutant. NH_3 is produced both by natural and man-made sources. Some natural sources of NH_3 include the decay of plant and animal material, animal waste and a small portion is released during respiration.

In Alberta, the fertilizer industry is the main industrial source of NH_3 (52%). The industry produces synthetic NH_3 for either direct application to the soils as a fertilizer or as a raw material in the production of other high nitrogen fertilizer products. The other major source of NH_3 is commercial feedlots where the large amounts of animal waste can be a significant source (40%).

4.12.2 Method of Monitoring

NH_3 is monitored continuously by the same principle as NO_2. In this method the air sample is split into two pathways. In the first, all NH_3 (as well as NO_2) in the sample is converted to NO by a catalyst and high temperatures (adding to the NO already in the sample). The concentration is measured by mixing the sample with O_3 and utilizing a chemiluminescence reaction to detect the amount of visible light produced. In the second pathway, at a temperature too low to convert NH_3, NO_2 is reduced to NO by a catalytic converter (adding to the NO already in the sample) and the chemiluminescence process repeated. The difference between the two readings is then calculated to be the concentration of NH_3.

4.12.3 Guidelines

The guideline for ambient ammonia concentrations is:

- 2.0 ppm as a 1-hour average.

4.12.4 Results

➢ **Fort Saskatchewan**

NH_3 is monitored at the Fort Saskatchewan monitoring station because of its proximity to the fertilizer industry. Figure 4-35 shows the frequency distribution of NH_3 concentrations by month and annual average concentrations. The maximum 1-hour average ammonia concentration in 1996 was 0.5 ppm. This value is 25% of the 1-hour guideline of 2.0 ppm. Ambient 1-hour ammonia concentrations were below the detection limit of the instrument over 95% of the time in 1996.

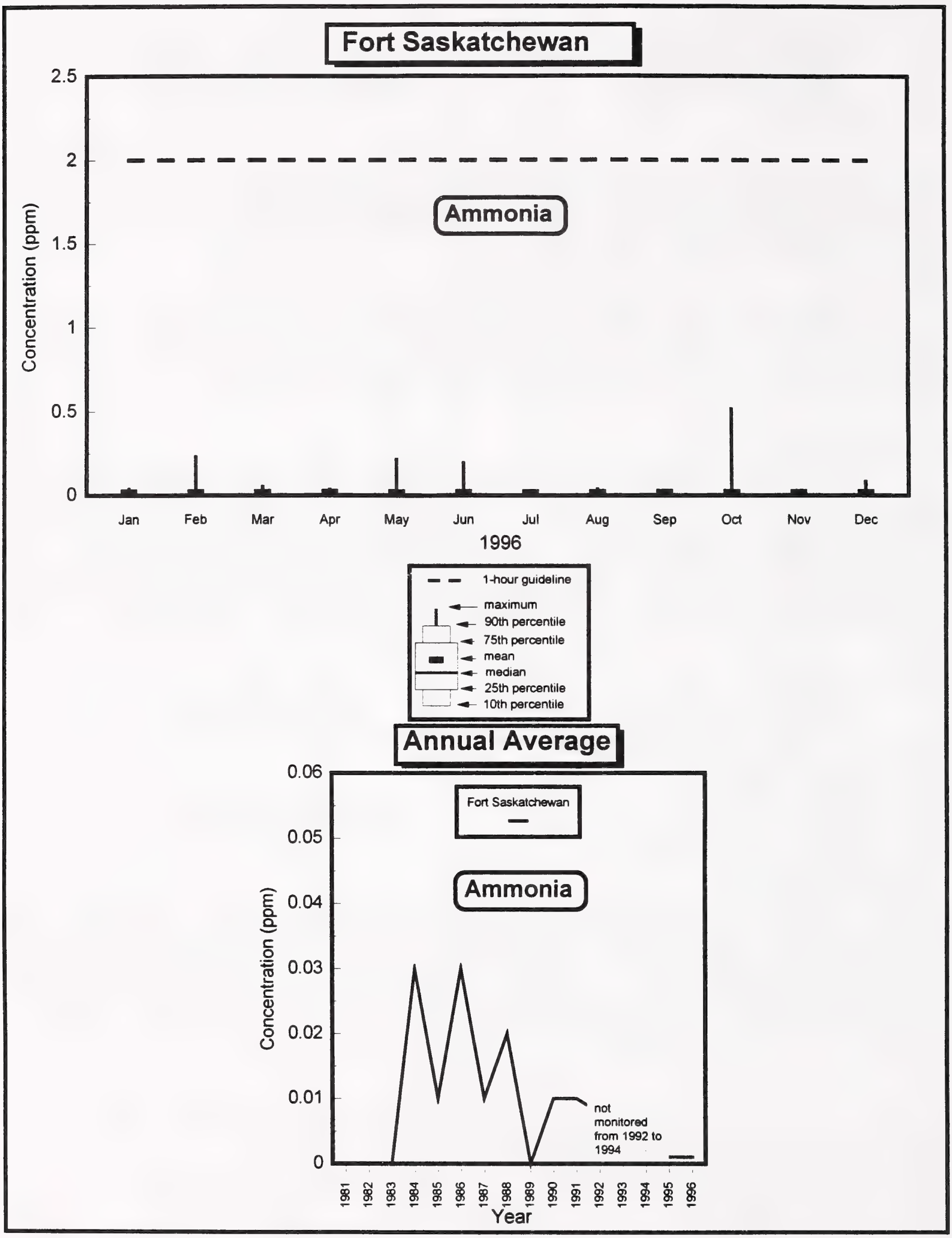


Figure 4-35 Frequency distribution of ammonia concentrations at Fort Saskatchewan.

5. INTERMITTENT MONITORING RESULTS

Data analysis has been conducted on intermittent air quality data to resolve, on a monthly basis, the maximum, minimum and mean loadings of specified parameters. A trend analysis was also performed on annual average parameter loadings using Daniel's trend test. This test is described in Section 4.

Parameters monitored on an intermittent basis (once every six days in accordance with the National Air Pollution Surveillance, or NAPS, schedule) include total suspended particulates (TSP), 8 polycyclic aromatic hydrocarbons (PAHs), sulphates and nitrates.

5.1 TOTAL SUSPENDED PARTICULATES (TSP)

5.1.1 Characteristics

Air pollutants exist not only in the gaseous form. Tiny particles of solid material or liquid aerosols, defined collectively as particulates, are also present in the air in great numbers, and may constitute an air pollution problem. The particles range in size from 0.001 to 500 micrometres (a human hair is about 100 micrometres in diameter) and, depending on their size and other properties, may remain suspended in the air for a few seconds or indefinitely (see Section 4.9 on Inhalable Particulates).

Suspended particles may result from a variety of natural and anthropogenic sources. These sources include vehicle exhaust emissions, industrial emission sources, soil, road dust, dust resulting from other human activities (i.e. agriculture), smoke from forest fires, smoke from recreational sources (i.e. campfires and fireplaces). Total suspended particulates and inhalable particulates are monitored by Alberta Environmental Protection.

5.1.2 Method of Monitoring

Total suspended particulates are measured by the high volume sampler. The sampler consists of a vacuum system and filter housed in a shelter and operates on the same principle as a vacuum cleaner. The TSP matter in the atmosphere is collected by drawing a known volume of air through a pre-weighed filter for a 24-hour period every sixth day according to the NAPS monitoring schedule. The filter is then re-weighed to determine the mass of the particles collected.

5.1.3 Guidelines

Guidelines governing the maximum permissible levels of TSP are based on visibility reduction and nuisance effects. Alberta has adopted the most rigorous federal standards for maximum TSP loadings:

- 100 $\mu g/m^3$ (micrograms per cubic meter) as a 24-hour total loading; and
- 60 $\mu g/m^3$ as an annual geometric mean loading.

5.1.4 Results

In 1996, total suspended particulates were monitored at all three Edmonton and Calgary monitoring stations, and at the Fort Saskatchewan and Royal Park monitoring stations. Minimum, mean and maximum TSP loadings are presented by month in Figures 5-1 to 5-3.

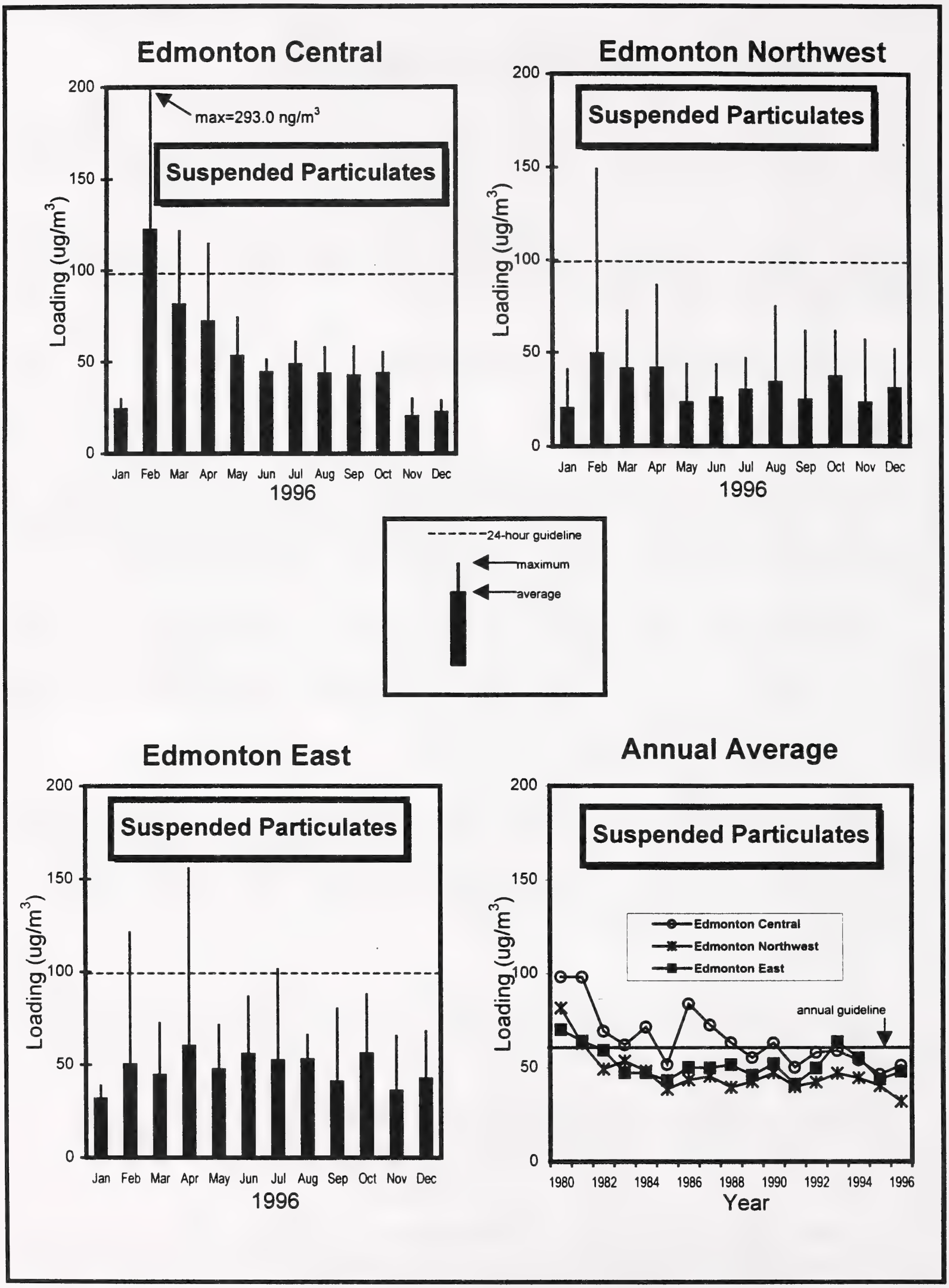


Figure 5-1 Frequency distribution of total suspended particulate loadings at Edmonton

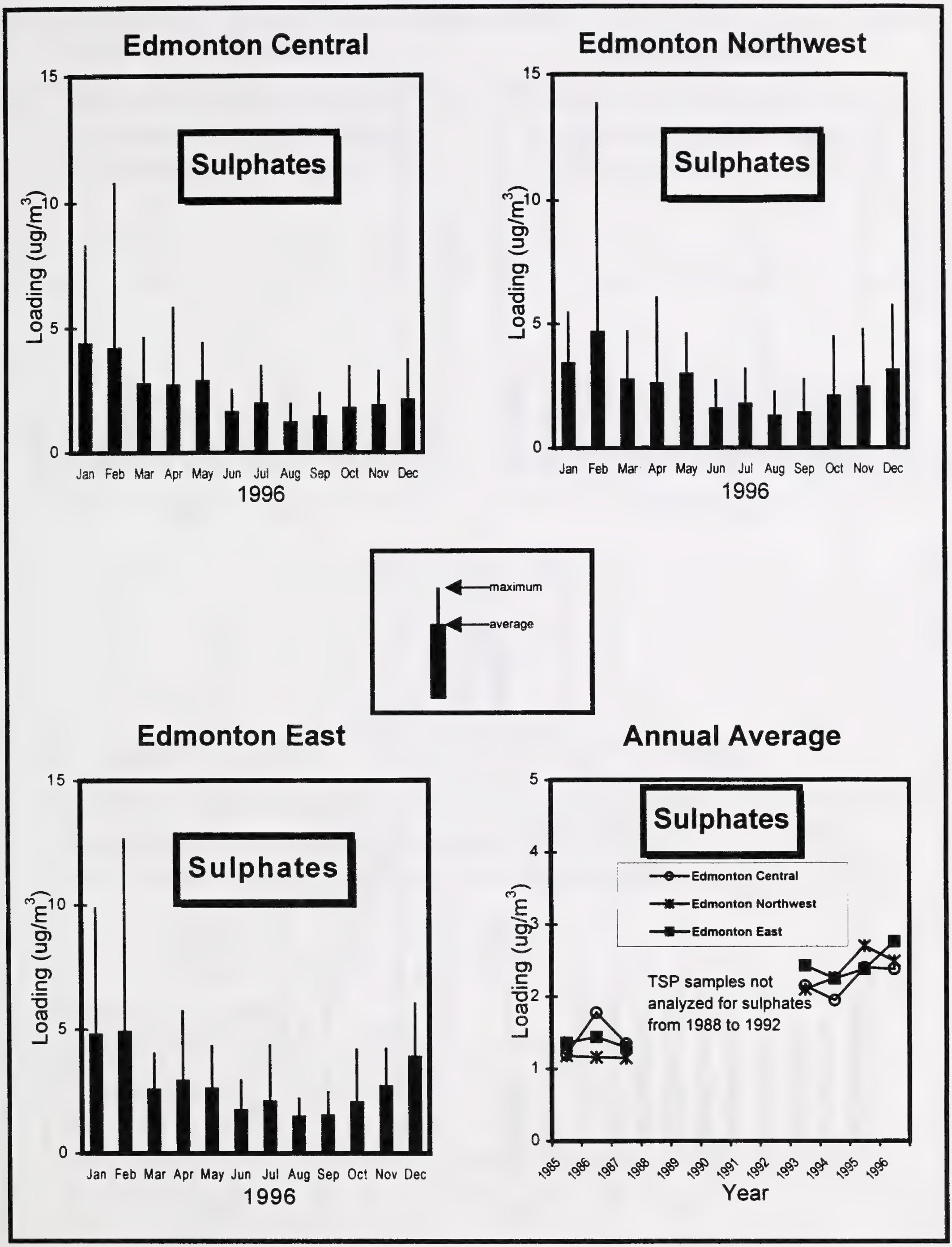


Figure 5-21 Frequency distribution of sulphate loadings at Edmonton

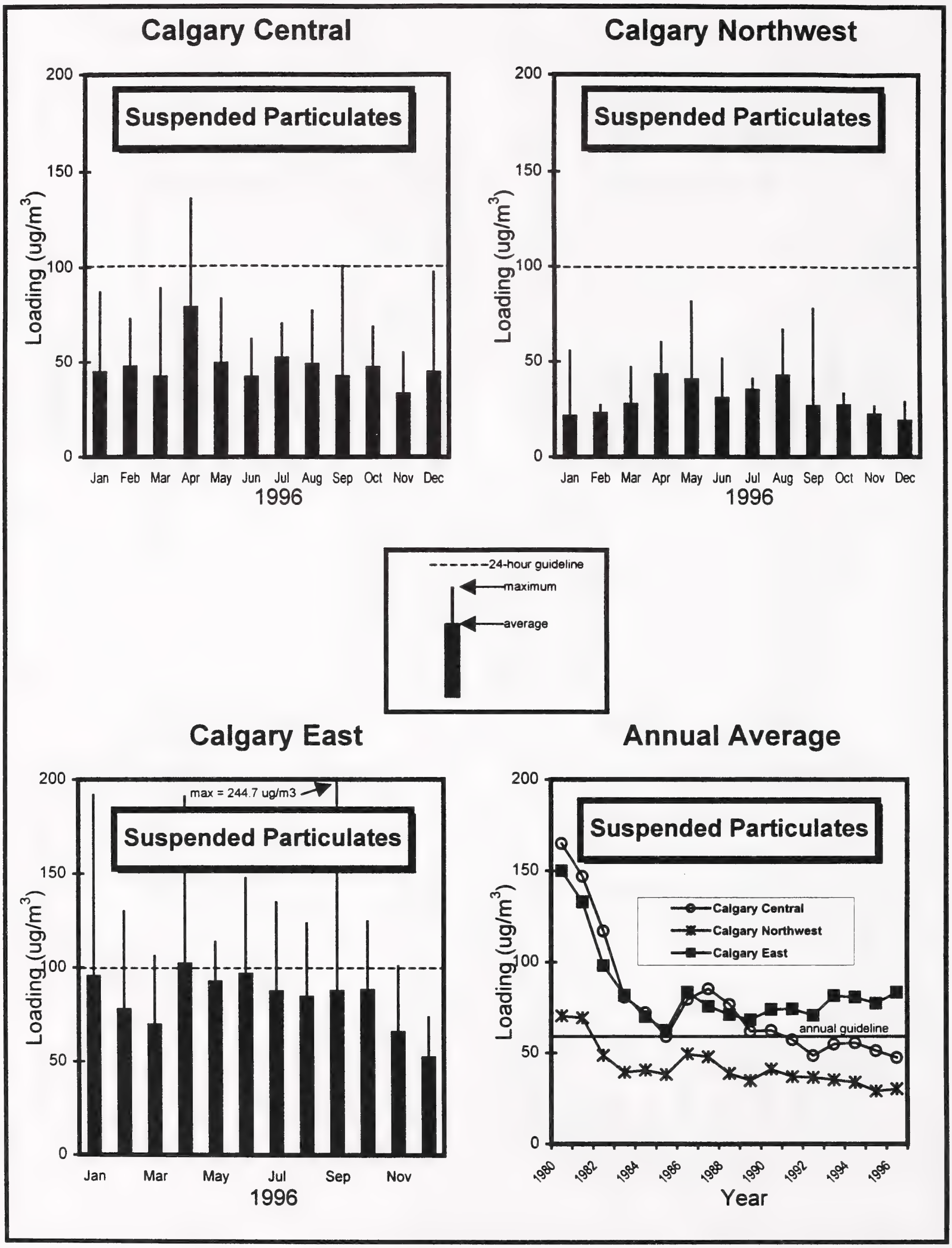


Figure 5-2 Frequency distribution of total suspended particulate loadings at Calgary

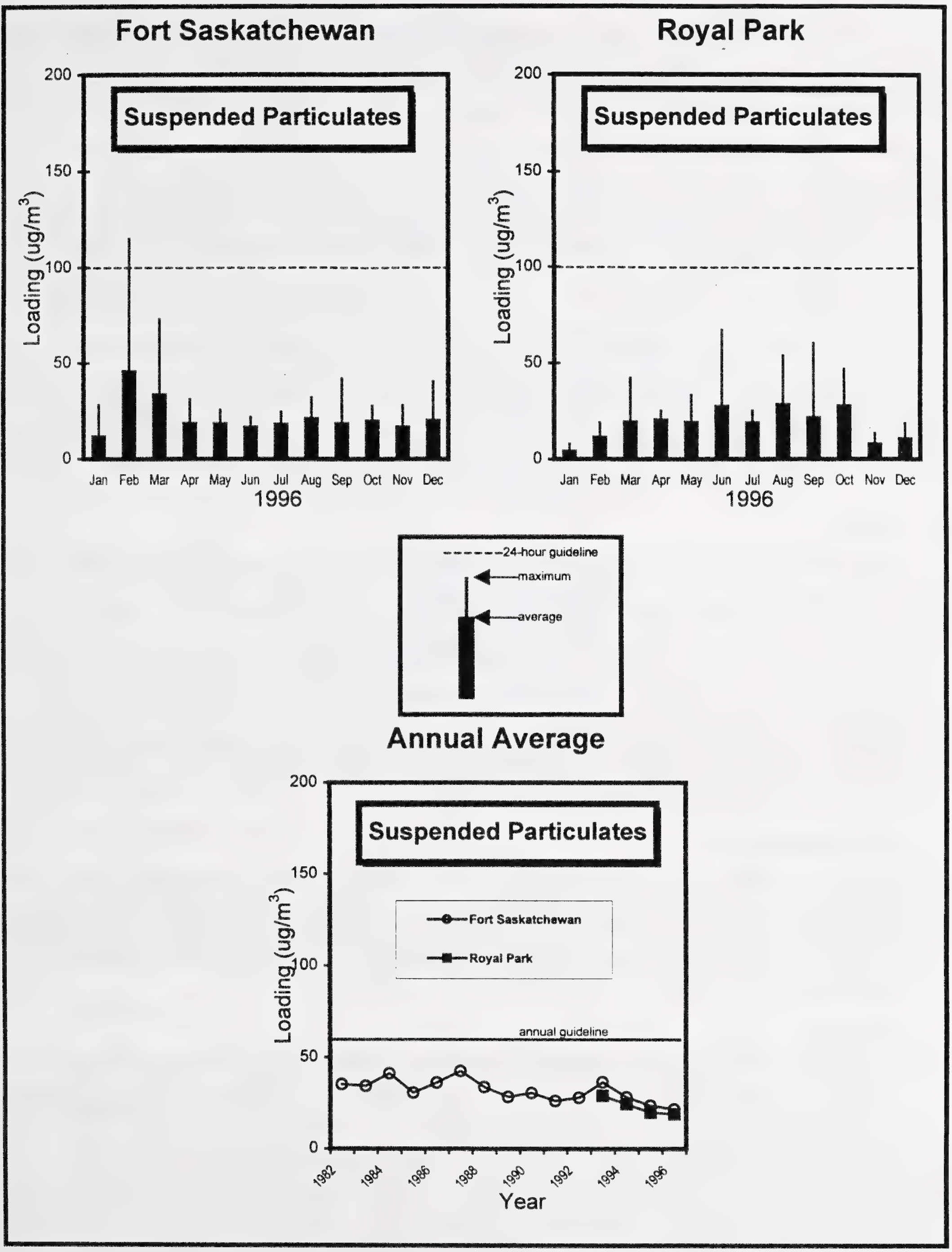


Figure 5-3 Frequency distribution of total suspended particulate loadings at Fort Saskatchewan and Royal Park

Annual average loadings of TSP ranged from 19.1 μg/m^3 at Royal Park to 83.4 μg/m^3 at the Calgary East monitoring location. Urban monitoring stations located in Edmonton and Calgary showed notably higher TSP loadings than the Fort Saskatchewan and Royal Park stations. The annual guideline for TSP of 60 μg/m^3 was exceeded only at the Calgary East monitoring station in 1996.

➢ *Edmonton*

In 1996, a total of 7 exceedances of the 24-hour guideline occurred at the Edmonton Central station, 1 exceedance occurred at the Northwest station, and 3 exceedances occurred at the East station. Annual average TSP loadings were 51.2, 32.0 and 47.9 μg/m^3 at the Central, Northwest and East stations, respectively. The highest frequency of exceedances were recorded in the winter and spring at all three stations, and also in the summer at the East station. Exceedances of the guideline for TSP may be attributed to the combination of: (1) vehicle emissions trapped by persistent inversions which do not allow pollutants to disperse rapidly; (2) sand and dust which is evident on most streets after spring thaw (especially central and northwest stations); and (3) dust transported into the city from agricultural activities (especially at the East station). A peak 24-hour TSP loading of 293.0 μg/m^3 was observed at the Edmonton Central monitoring station in February. A decrease in annual average TSP loading is indicated at the Central and Northwest monitoring stations.

➢ *Calgary*

Exceedances of the 24-hour guideline for TSP were recorded most frequently at the Calgary East monitoring location in 1996 with a total of 18 exceedances. The 24-hour guideline of 100 μg/m^3 was exceeded 3 times at the Central station. The guideline was not exceeded at the Northwest station. Exceedances occurred in April and September at the Central station, and year round (with the exception of December) at the East station. The maximum TSP loading observed in Calgary was 244.7 μg/m^3 which occurred in September at the East station. The annual average guideline of 60 μg/m^3 was also exceeded at the Calgary East monitoring station where a value of 83.4 μg/m^3 was recorded. High TSP loadings at the Calgary East monitoring station were due primarily to road dust and vehicle exhaust emissions. A significant decrease in the long-term average TSP loadings is evident at the Central and Northwest monitoring stations.

➢ *Fort Saskatchewan*

The 24-hour guideline for TSP loading was exceeded once at the Fort Saskatchewan high-volume monitoring station in 1996. The overall maximum TSP loading was 114.7 μg/m^3 On average, the highest TSP values were recorded in the winter and spring seasons. Road dust and agricultural activities are major sources of suspended particulates at this location. A significant downward trend in annual average TSP loadings is evident at the Fort Saskatchewan station.

➢ *Royal Park*

The maximum 24-hour average TSP value recorded at the Royal Park station was 66.9 μg/m^3. This value was recorded in June and is below the 24-hour guideline of 100 μg/m^3. TSP loadings were generally higher in the autumn months at the Royal Park station. Sources of particulates in the Vegreville area are agricultural activities and road dust.

5.2 POLYCYLIC AROMATIC HYDROCARBONS (PAH)

5.2.1 Characteristics

Polycyclic aromatic hydrocarbons are a class of chemicals that are formed during the incomplete combustion of gasoline, diesel, oil, coal, wood, garbage and other organic substances. There are more than 100 different PAHs with varying levels of toxicity. PAHs usually occur as complex mixtures (contained in soot and smoke) rather than single compounds. PAHs occur in the atmosphere in the vapour phase or attached to dust particles. Tobacco smoke and charbroiled meats are common sources of PAHs. Other outdoor sources of PAHs include vehicle exhaust emissions, wood smoke from fireplaces, smoke from forest fires and industrial facilities.

In 1996 Alberta Environmental Protection monitored for 8 of the most common PAHs. Prior to 1996, only the most well-known PAH, benzo(a)pyrene (B(a)P), was monitored at all the intermittent stations. The majority of the PAHs measured by Alberta Environmental Protection appear on the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR) list of hazardous substances (U.S. Department of Health and Human Services, 1995). The list of hazardous substances is ranked from most toxic to least toxic. The PAHs monitored by Alberta Environmental Protection and their associated rank are indicated below:

- benzo(a)pyrene (rank of 8);
- benzo(b,k)fluoranthene (rank of 10);
- dibenzo(a,h)anthracene (rank of 17);
- benzo(a)anthracene (rank of 37);
- benzo(e)pyrene (rank of 47);
- chrysene (rank of 113); and
- indeno(1,2,3-c,d)pyrene (rank of 161).

Benzo(k)fluoranthene and benzo(g,h,i)perylene do not appear on the ATSDR list of hazardous substances. PAHs are also recognized on the Environment Canada Priority Substances List as parameters that are considered to be toxic.

5.2.2 Method of Monitoring

PAHs are monitored every sixth day at all high-volume monitoring stations in accordance with the NAPS monitoring schedule. High-volume filters undergo laboratory analysis using GC/MS (gas chromatography/mass spectrometry) to quantify the amount of PAH's in the sample. The results are 24-hour accumulated loadings of PAHs expressed in nanograms per cubic meter (ng/m^3).

5.2.3 Guidelines

Alberta Environmental Protection does not currently have guidelines for ambient concentrations of PAHs.

5.2.4 Results

Polycyclic aromatic hydrocarbons were monitored at all three Edmonton and Calgary air quality monitoring stations as well as at the Fort Saskatchewan and Royal Park stations. A seasonal trend in PAH concentrations is obvious at all monitoring stations. Much higher concentrations were evident in the fall and winter than in the spring and summer seasons. During the winter, meteorological conditions that retard the dispersion of pollutants, such as inversions and low wind speeds, tend to be more prevalent. A second contributing factor is that automobile engines run less efficiently during cold temperatures which leads to an increase in PAH emissions. Annual average concentrations are much higher at monitoring stations located in the vicinity of heavily used traffic arteries, or where vehicle emissions are transported to the monitoring site. Minimum, maximum and mean PAH concentrations are presented in Figures 5-4 to 5-21 for each of the different PAHs at each monitoring station. Table 5-1 gives the annual average concentration for each polycyclic aromatic hydrocarbon monitored in 1996.

Table 5-1 Annual average concentration of polycyclic aromatic hydrocarbons in 1996.

Polycyclic Aromatic Hydrocarbon (PAH) (ng/m^3)	Location							
	Edmonton Central	Edmonton Northwest	Edmonton East	Calgary Central	Calgary Northwest	Calgary East	Fort Saskatchewan	Royal Park
Benzo(a)pyrene	0.20	0.22	0.11	0.17	0.07	0.21	0.07	0.01
Chrysene	0.24	0.26	0.21	0.20	0.12	0.32	0.13	0.04
Benzo(b,k)fluoranthene	0.38	0.38	0.23	0.29	0.17	0.44	0.15	0.03
Benzo(e)pyrene*	0.34	0.58	0.32	0.45	0.21	0.47	0.21	0.06
Benzo(a)anthracene	0.13	0.17	0.10	0.10	0.06	0.16	0.06	0.01
Indeno(1,2,3-c,d)pyrene	0.28	0.33	0.16	0.26	0.13	0.32	0.12	0.02
Dibenzo(a,h)anthracene	0.01	0.02	0.02	0.01	0.00	0.02	0.01	0.00
Benzo(g,h,i)perylene	0.70	0.75	0.34	0.77	0.28	0.75	0.23	0.03

*3-month average, benzo(e)pyrene only monitored from Oct. to Dec. 1996.

➢ *Edmonton*

PAH concentrations were generally much higher at the Edmonton Central and Northwest monitoring stations in comparison to the East monitoring station. Vehicular traffic is substantially higher in the vicinity of the Central and Northwest monitoring stations and is likely the reason for higher concentrations at these stations. Average and peak concentrations for all PAHs were measured in the late fall and early winter at all Edmonton stations. A maximum B(a)P concentration of 1.30 ng/m^3 was observed in November at the Edmonton Northwest monitoring station. B(a)P shows a slight upward trend in annual average loadings based on 14 years of data at the Northwest station. However, a significant dip in B(a)P concentrations is indicated in 1991 and 1992.

➢ *Calgary*

PAH concentrations were generally higher at the Calgary Central and East monitoring stations than at the Northwest station. Increased vehicular traffic in the vicinity of the Central and transport of these emissions to the East station are likely the causes of higher concentrations at these locations. The highest PAH concentrations were measured in the late fall and winter seasons at all Calgary monitoring stations. The maximum PAH concentration was benzo(b,k)fluoranthene with a peak of 2.17 ng/m^3 recorded in January. Average B(a)P loadings at Calgary stations ranged from 0.07 ng/m^3 at the Northwest station to 0.21 µg/ m^3 at the East station. The transport of pollutants from downtown Calgary is the major sources of PAHs at the East monitoring location. A peak B(a)P concentration of

1.40 ng/m^3 was recorded in December at the Central monitoring station. A trend in annual average B(a)P loadings is not evident at any Calgary monitoring stations based on 15 years of data.

- ### Fort Saskatchewan

Annual average PAH concentrations at Fort Saskatchewan were much lower than in downtown Edmonton and Calgary. The maximum PAH concentration was benzo(g,h,i)perylene with a value of 1.20 ng/m^3 recorded in December. The maximum B(a)P concentration was 0.45 ng/m^3 and was observed in January and December. B(a)P does not show a trend in annual average values at Fort Saskatchewan based on 15 years of data.

- ### Royal Park

PAH concentrations were much lower at Royal Park than any other monitoring stations because of the rural location of the station. The highest PAH concentration was benzo(b,k)fluoranthene with an annual average concentration of 0.03 ng/m^3 and a peak concentration of 0.25 ng/m^3 recorded in February. The maximum B(a)P loading at the Royal Park station was 0.08 ng/m^3 which was also recorded in February.

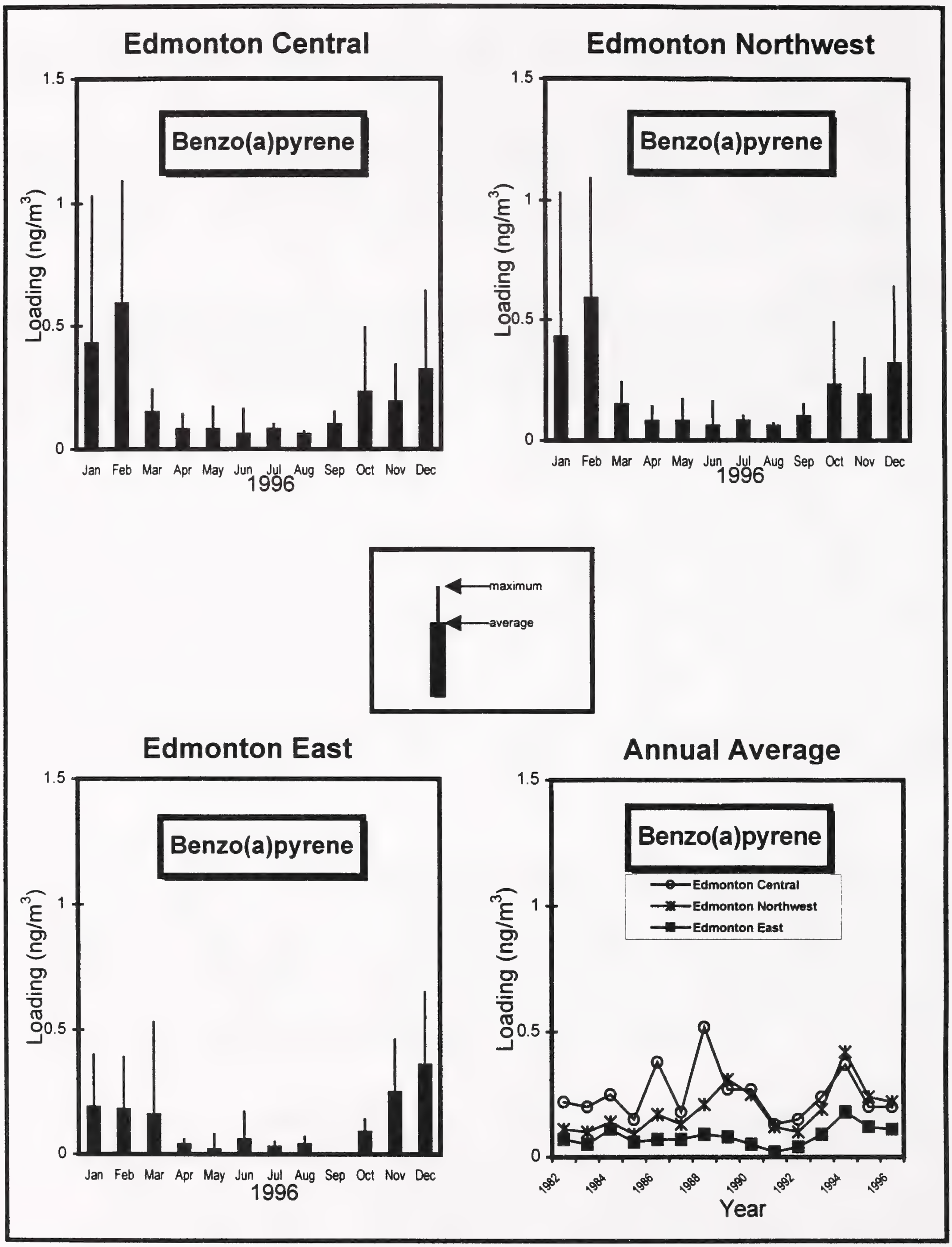


Figure 5-4 Frequency distribution of benzo(a)pyrene loadings at Edmonton

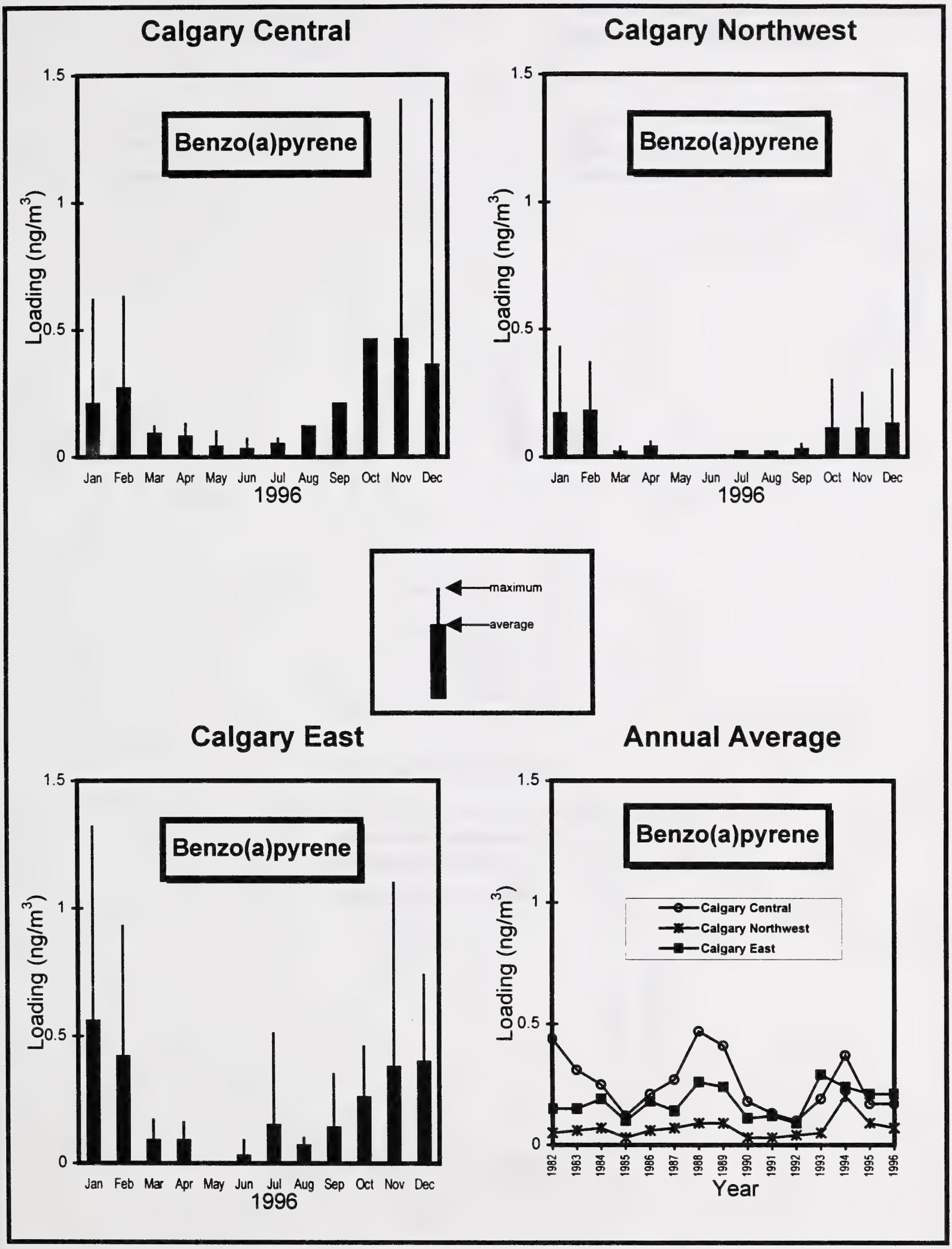


Figure 5-5 Frequency distribution of benzo(a)pyrene loadings at Calgary

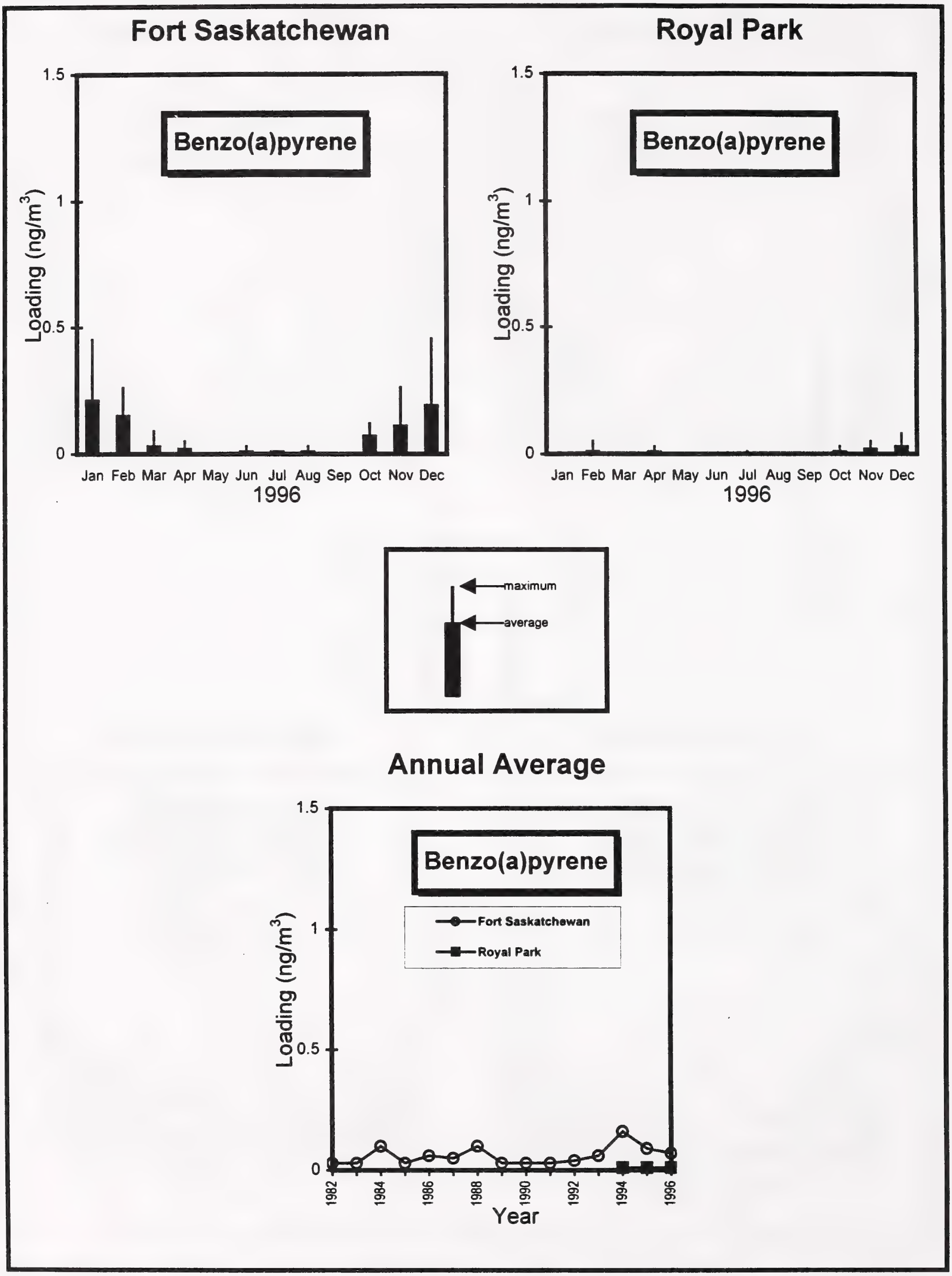


Figure 5-6 Frequency distribution of benzo(a)pyrene loadings at Fort Saskatchewan and Royal Park

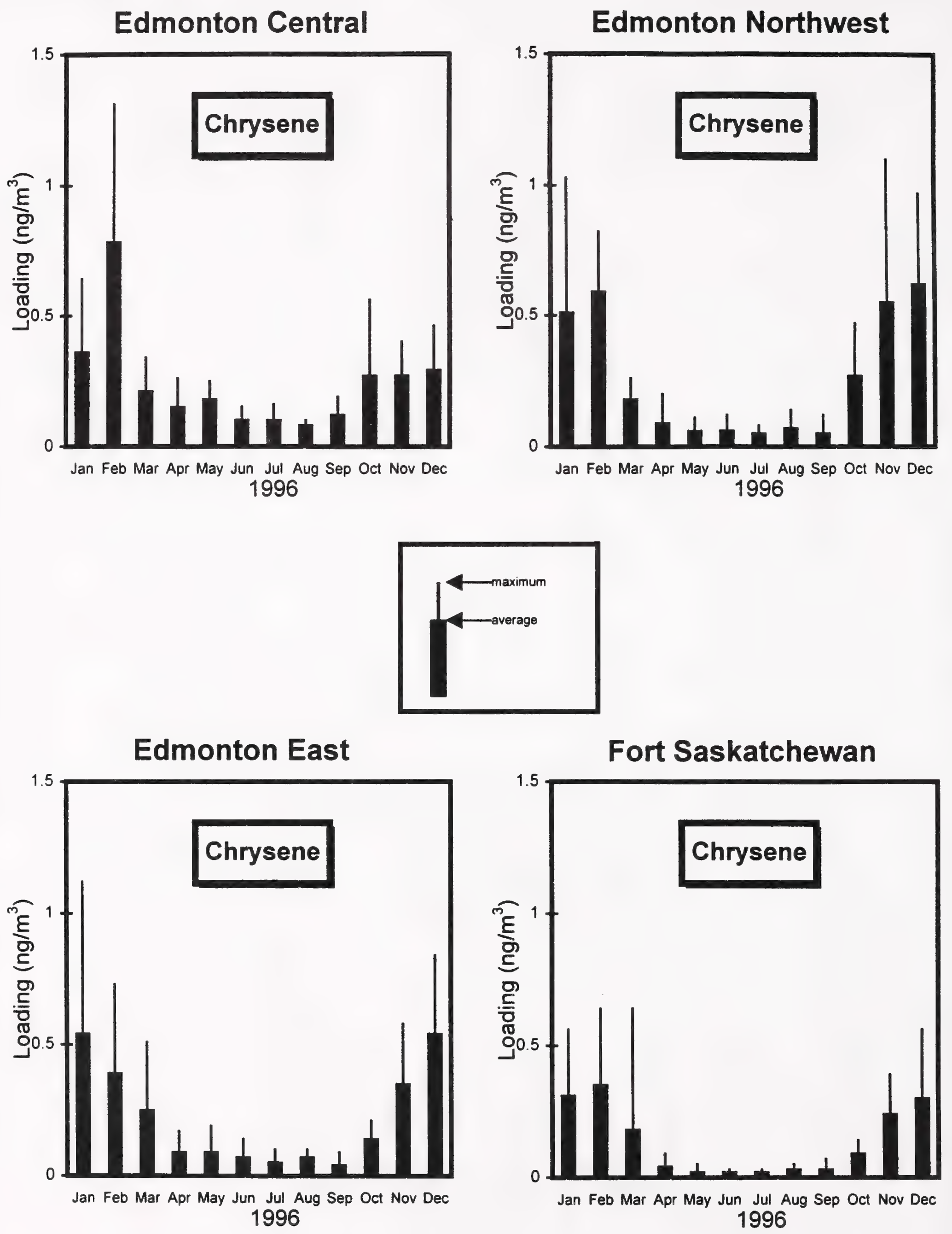


Figure 5-7 **Frequency distribution of chrysene loadings at Edmonton and Fort Saskatchewan**

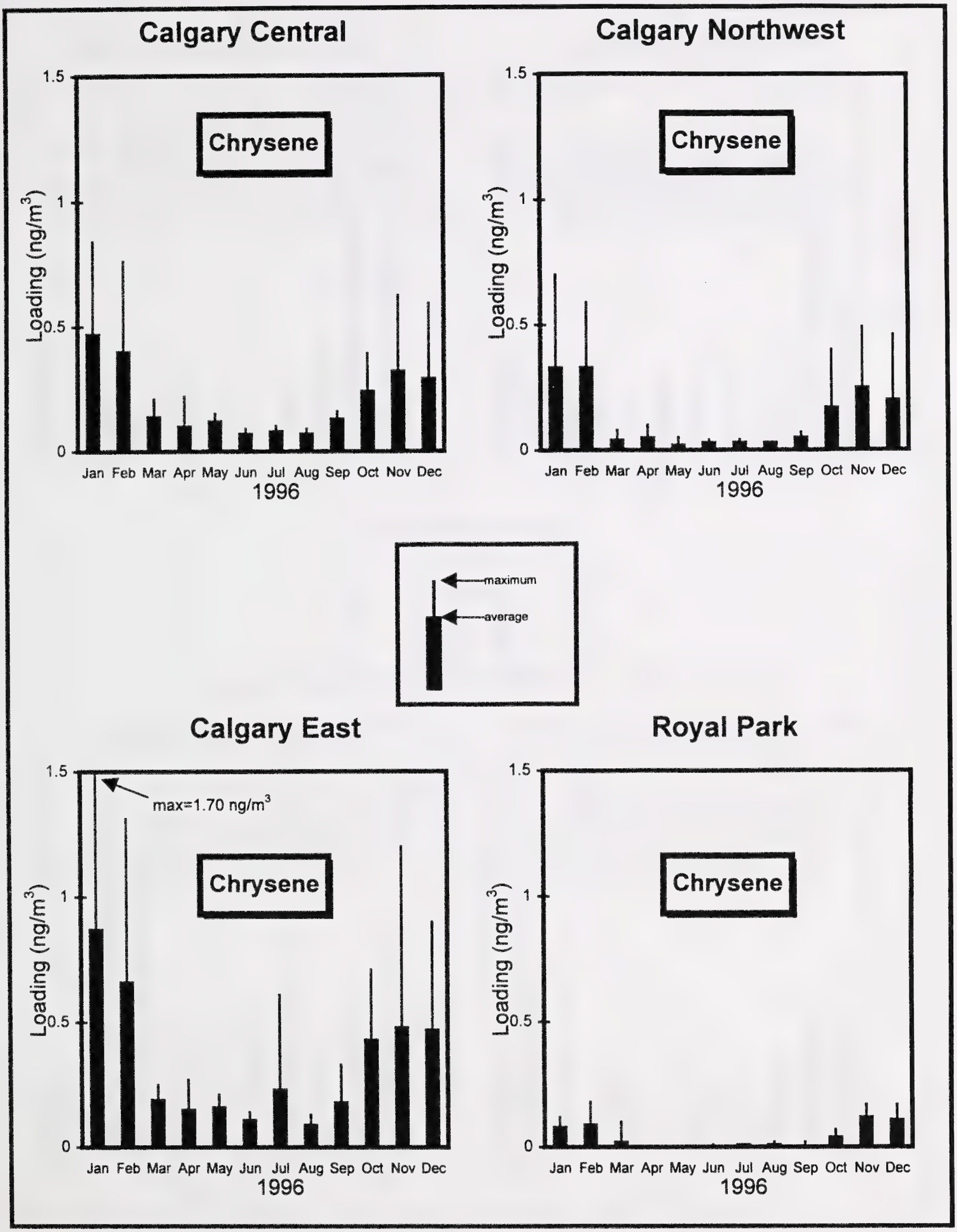


Figure 5-8 Frequency distribution of chrysene loadings at Calgary and Royal Park

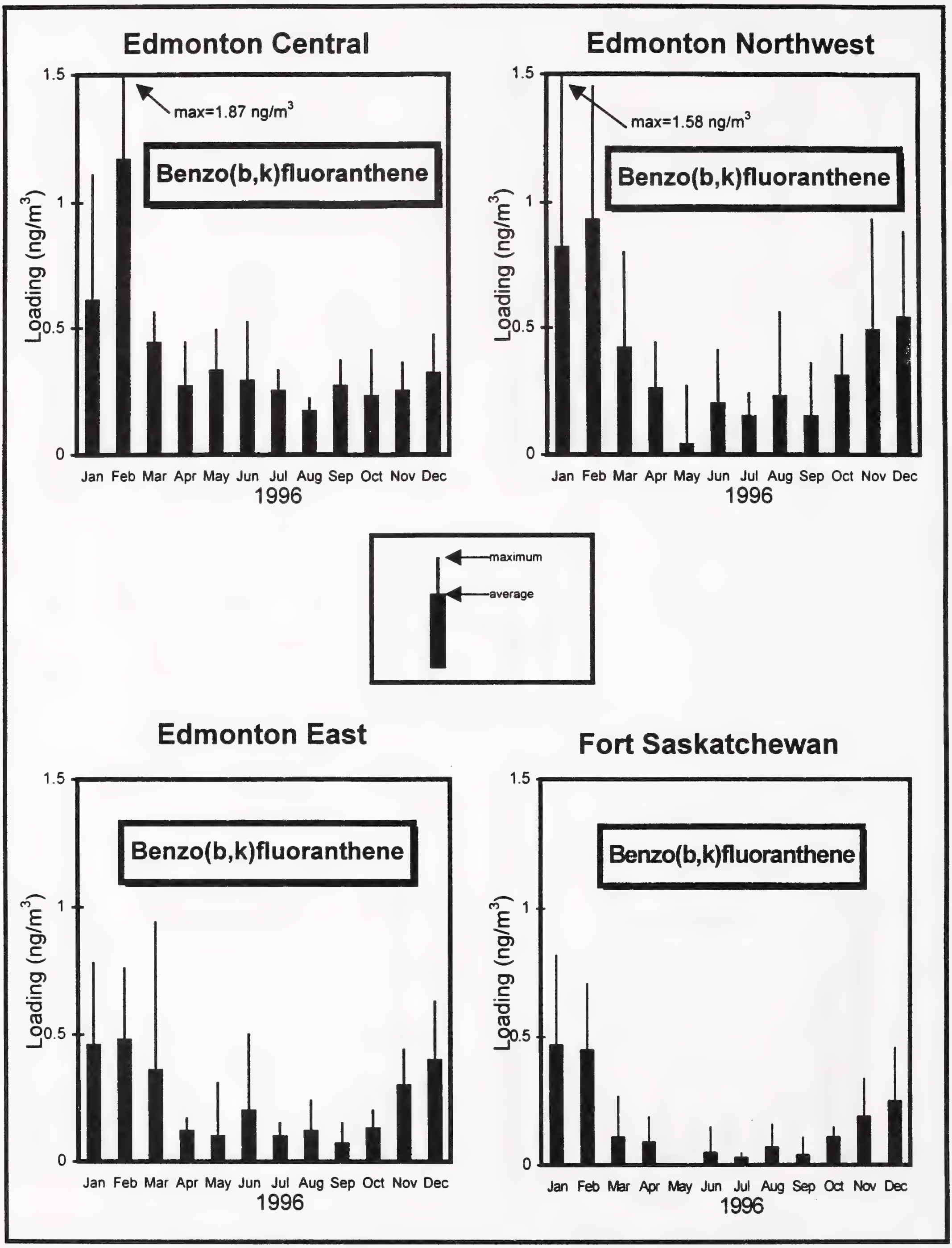


Figure 5-9 **Frequency distribution of benzo(b,k)fluoranthene loadings at Edmonton and Fort Saskatchewan**

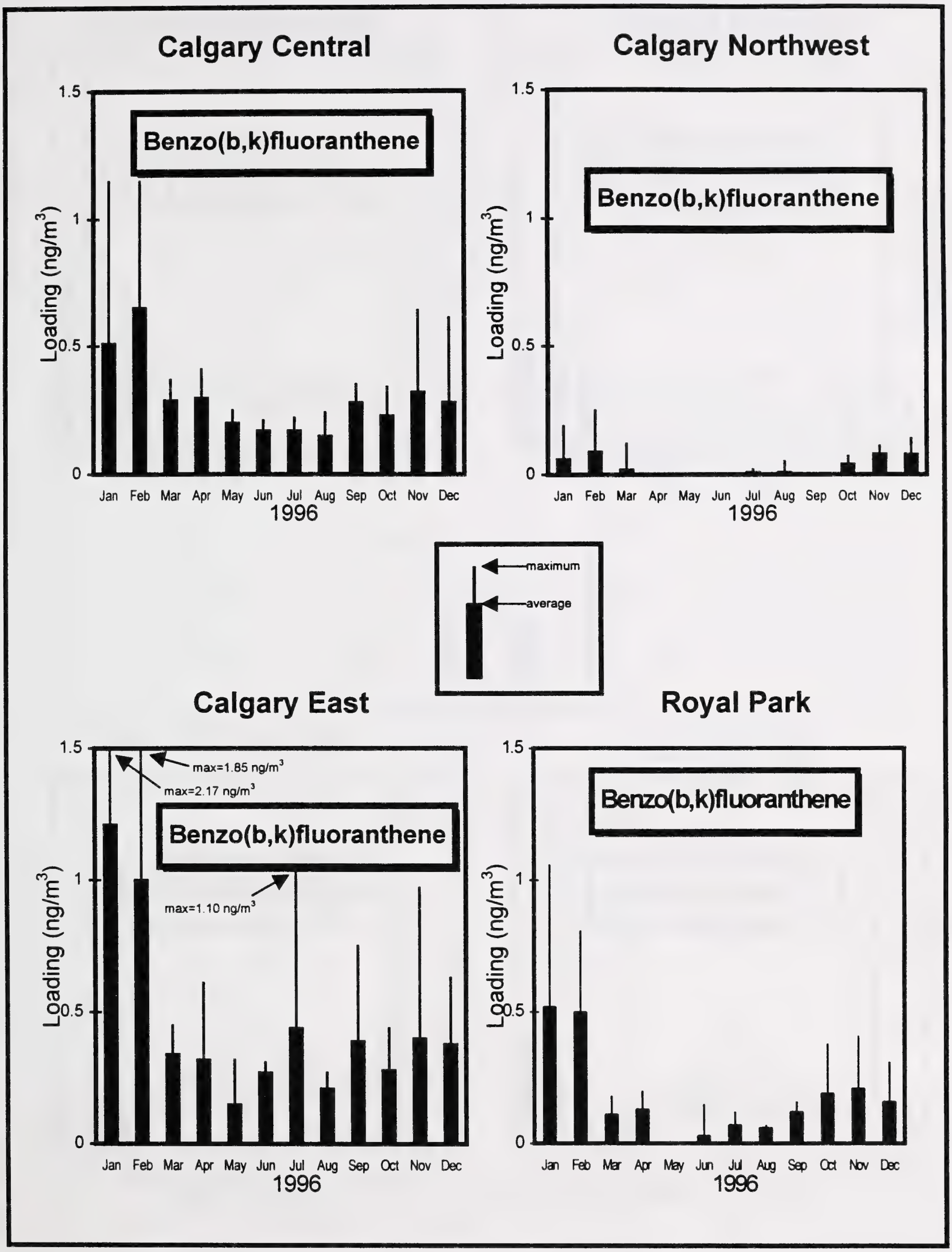


Figure 5-10 Frequency distribution of benzo(b,k)fluoranthene loadings at Calgary and Royal Park

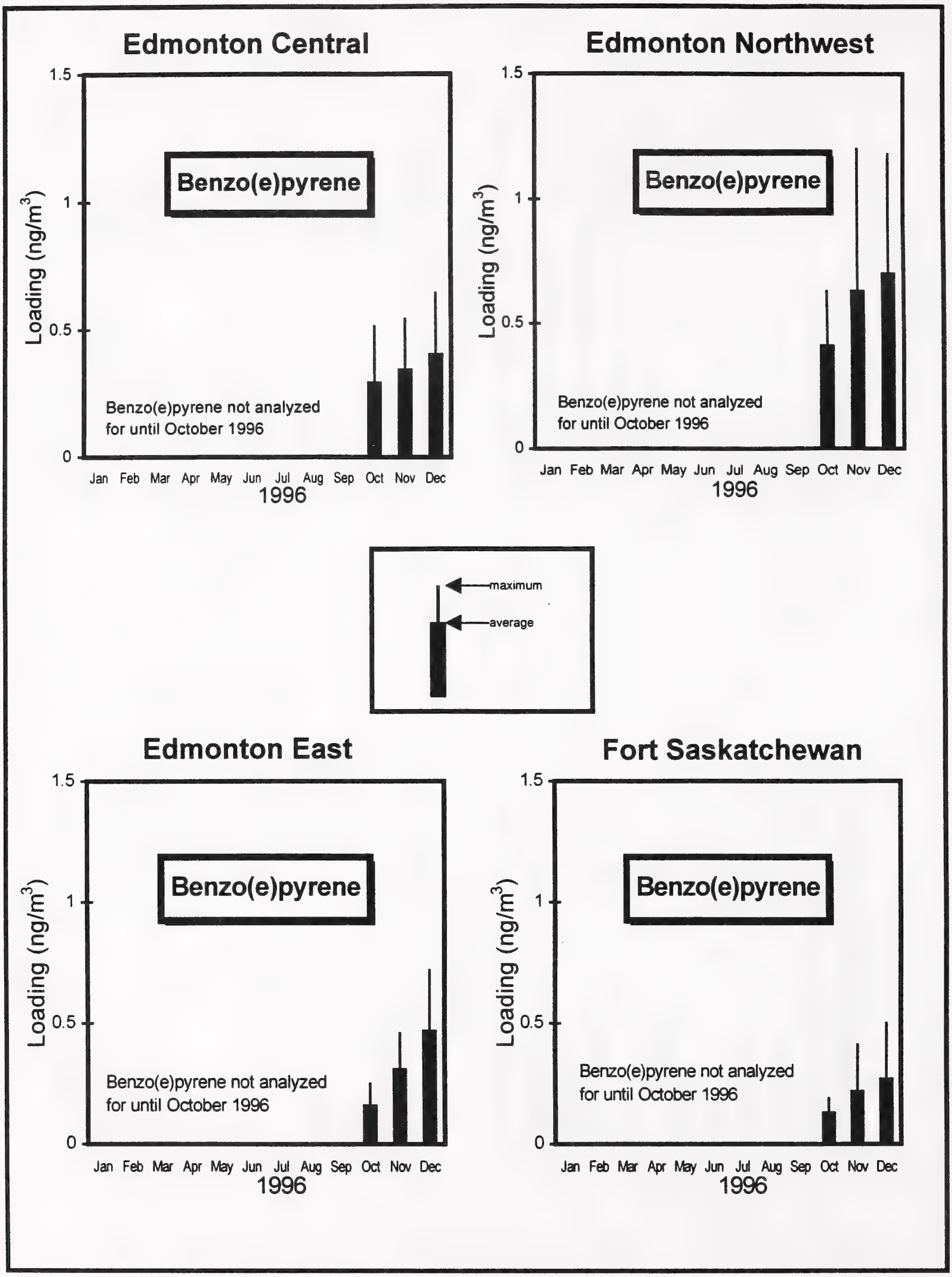


Figure 5-11 **Frequency distribution of benzo(e)pyrene loadings at Edmonton and Fort Saskatchewan**

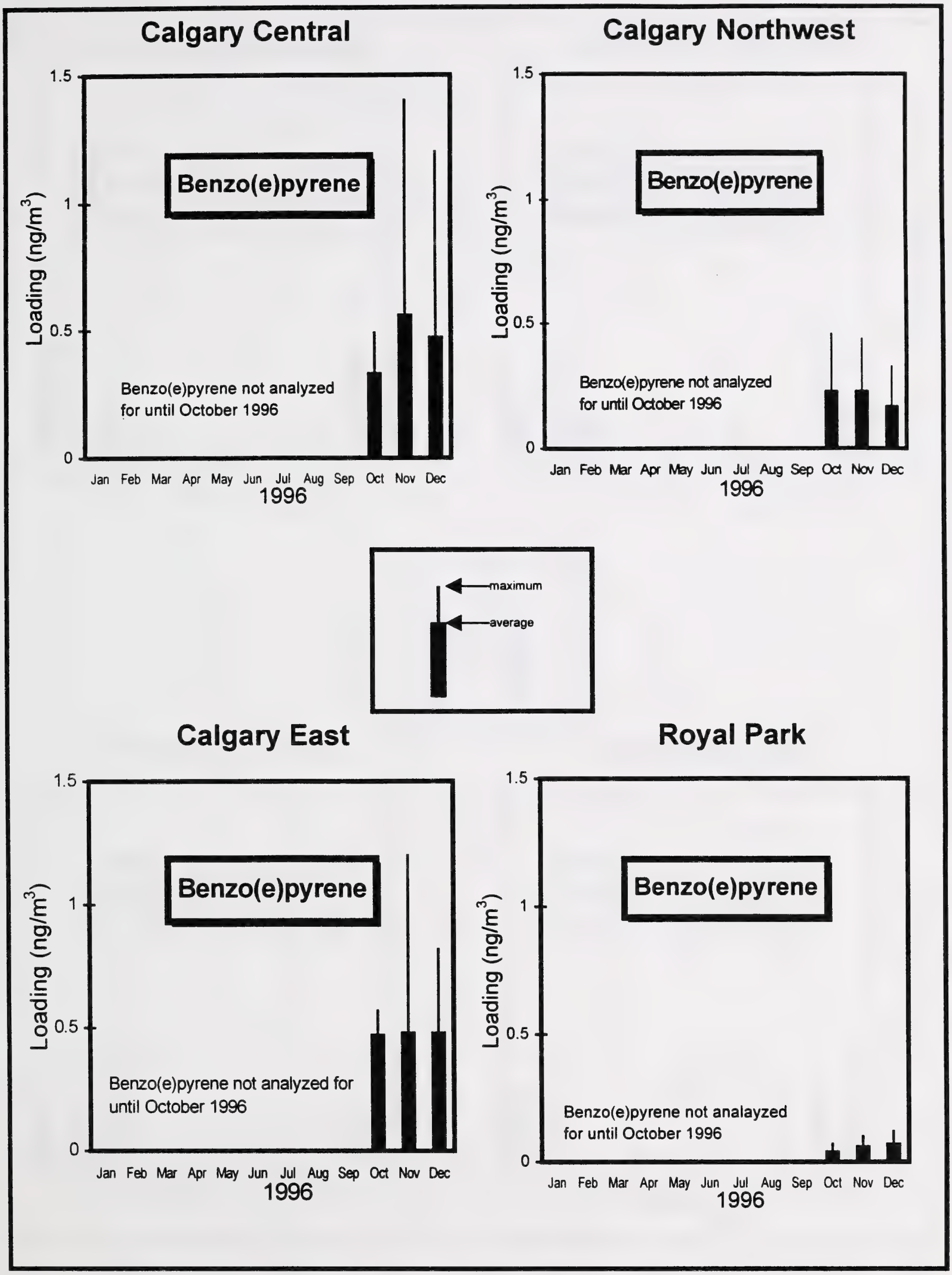


Figure 5-12 Frequency distribution of benzo(e)pyrene loadings at Calgary and Royal Park

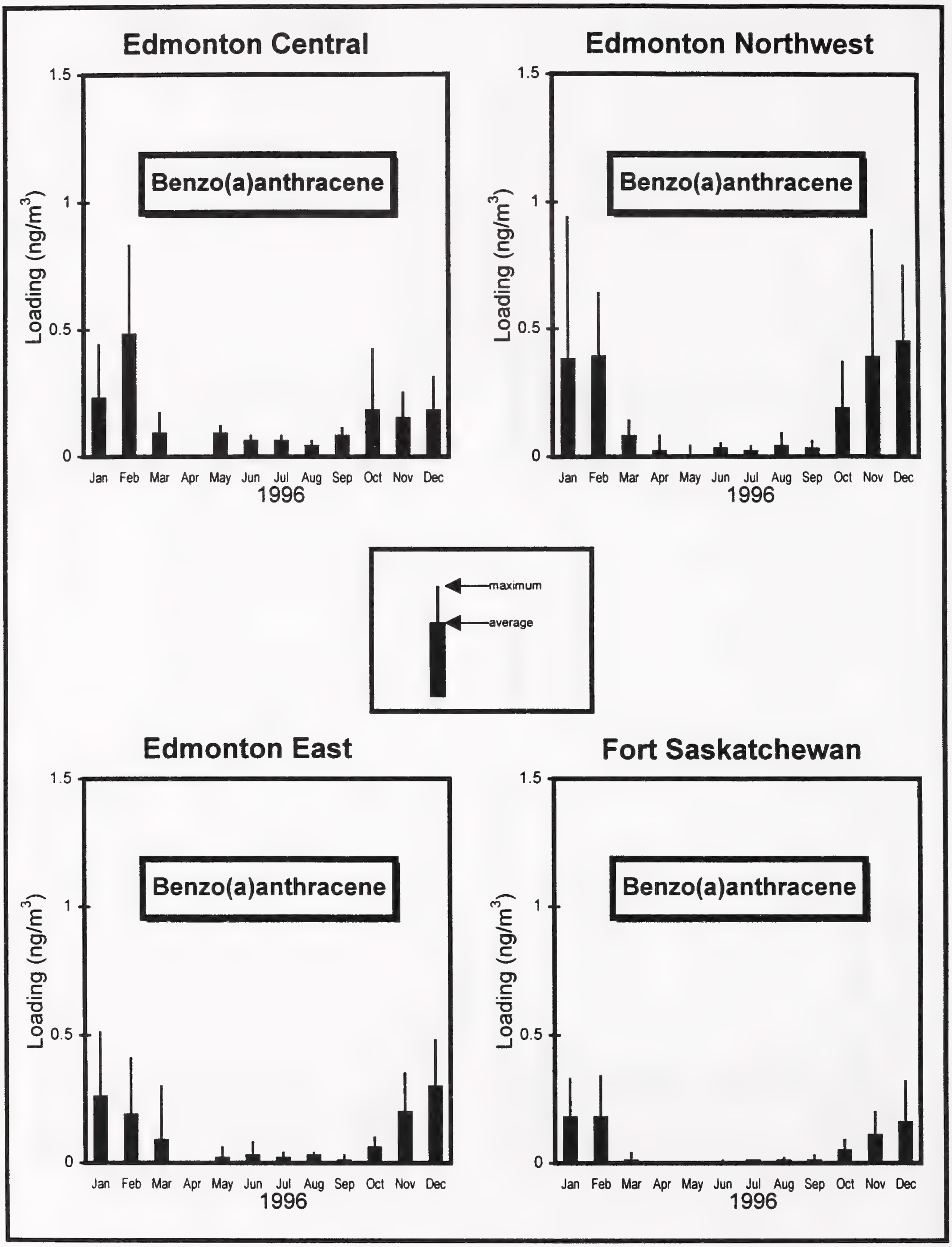


Figure 5-13 **Frequency distribution of benzo(a)anthracene loadings at Edmonton and Fort Saskatchewan**

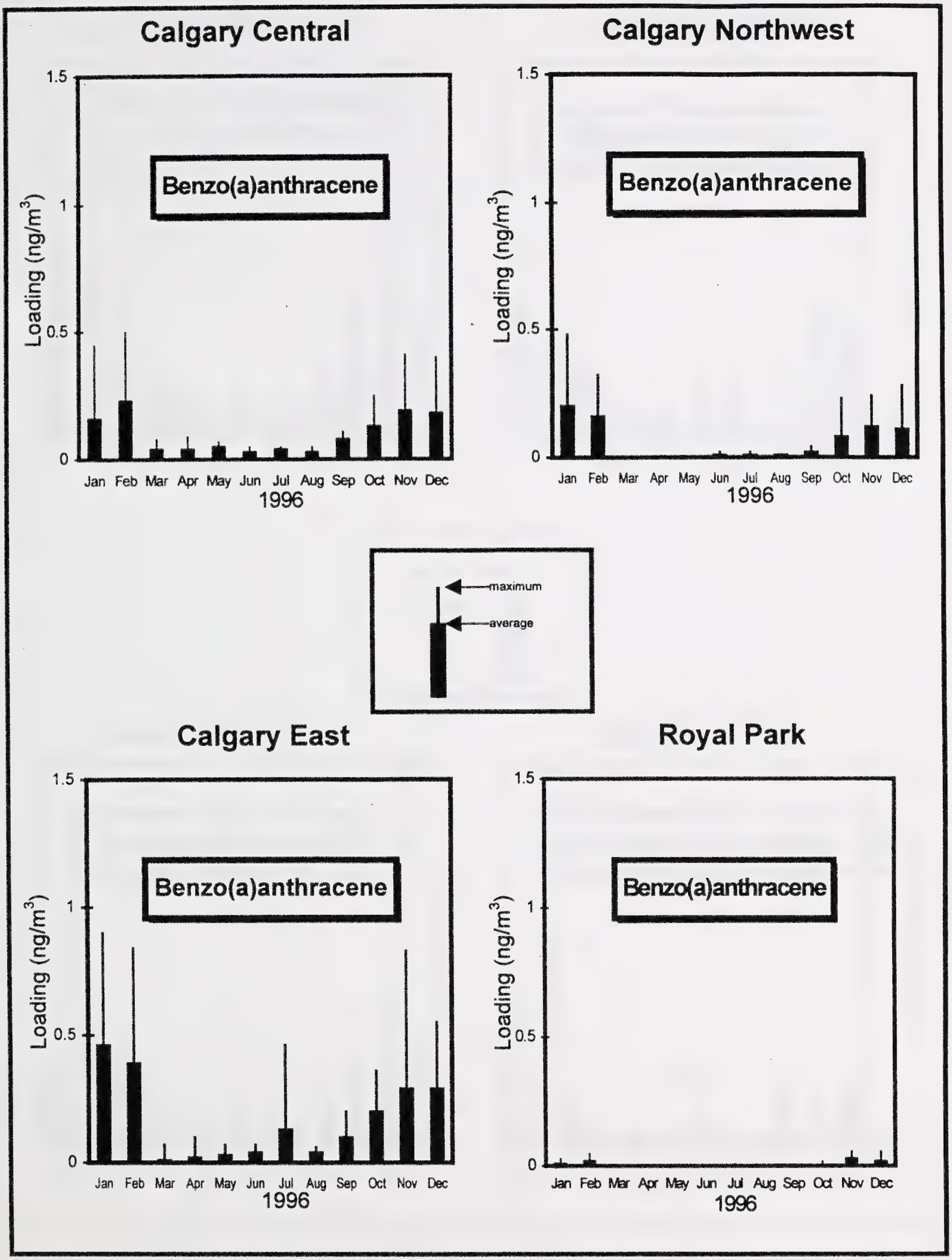


Figure 5-14 **Frequency distribution of benzo(a)anthracene loadings at Calgary and Royal Park**

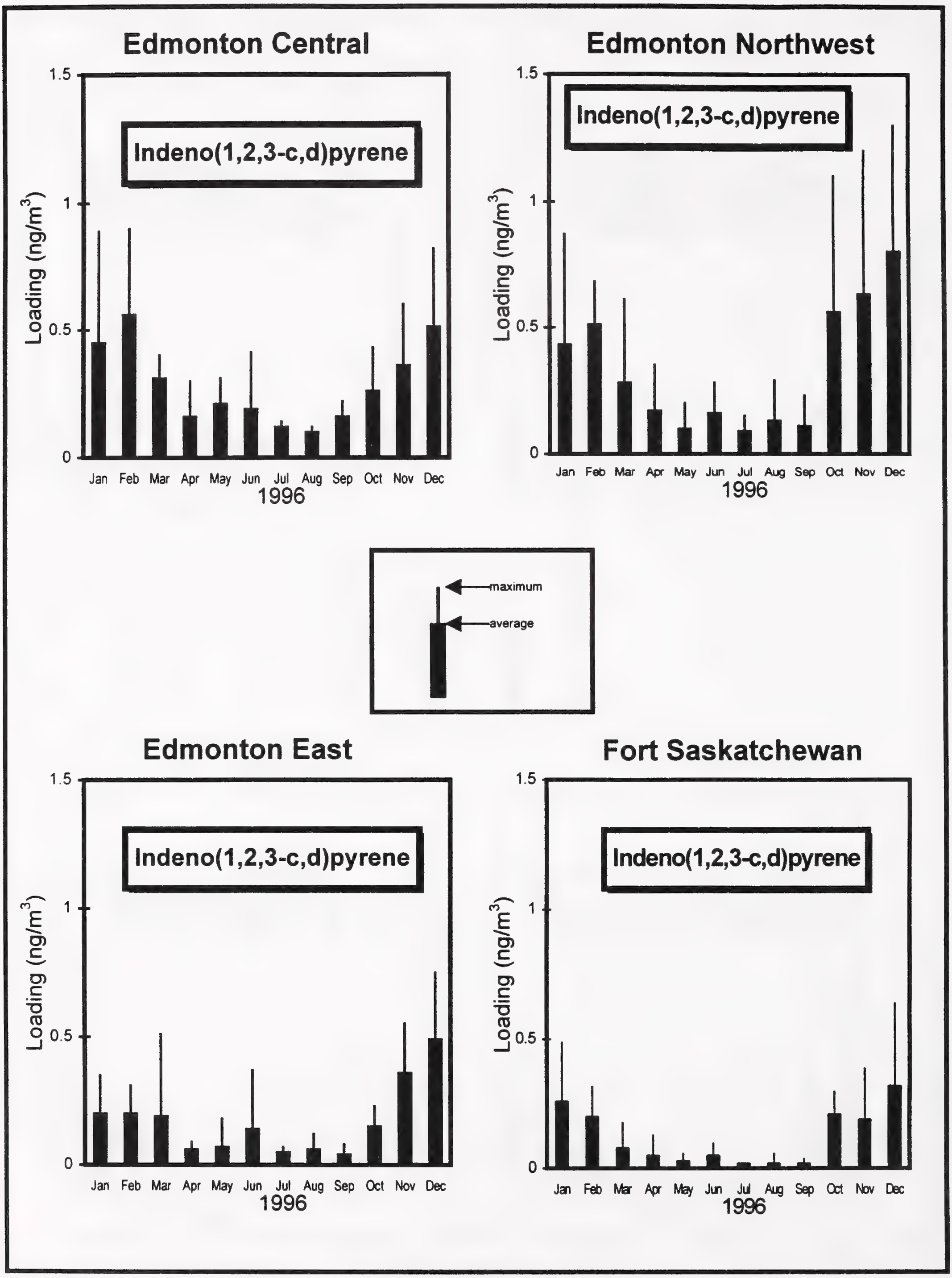


Figure 5-15 **Frequency distribution of indeno(1,2,3-c,d)pyrene loadings at Edmonton and Fort Saskatchewan**

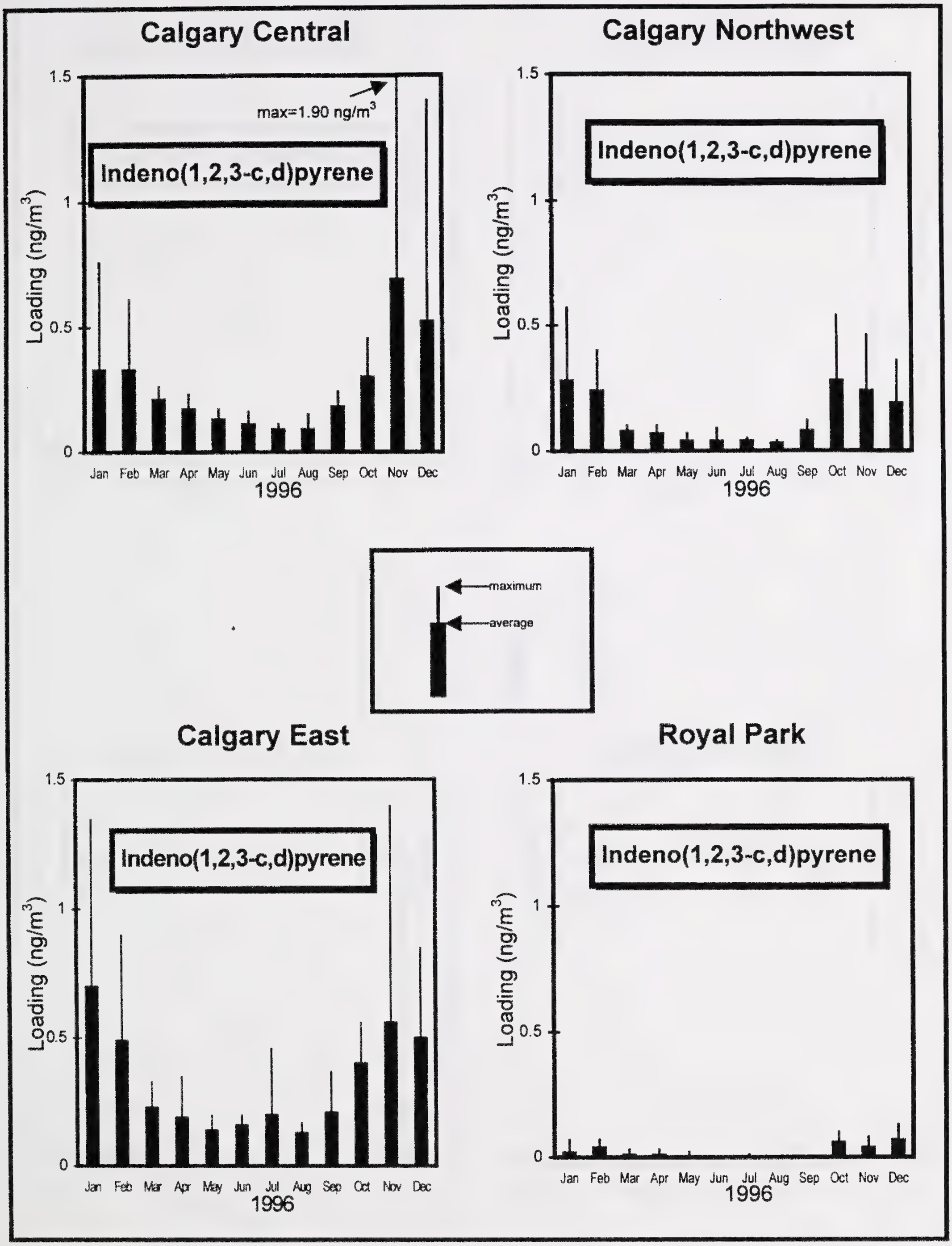


Figure 5-16 Frequency distribution of indeno(1,2,3-c,d)pyrene loadings at Calgary and Royal Park

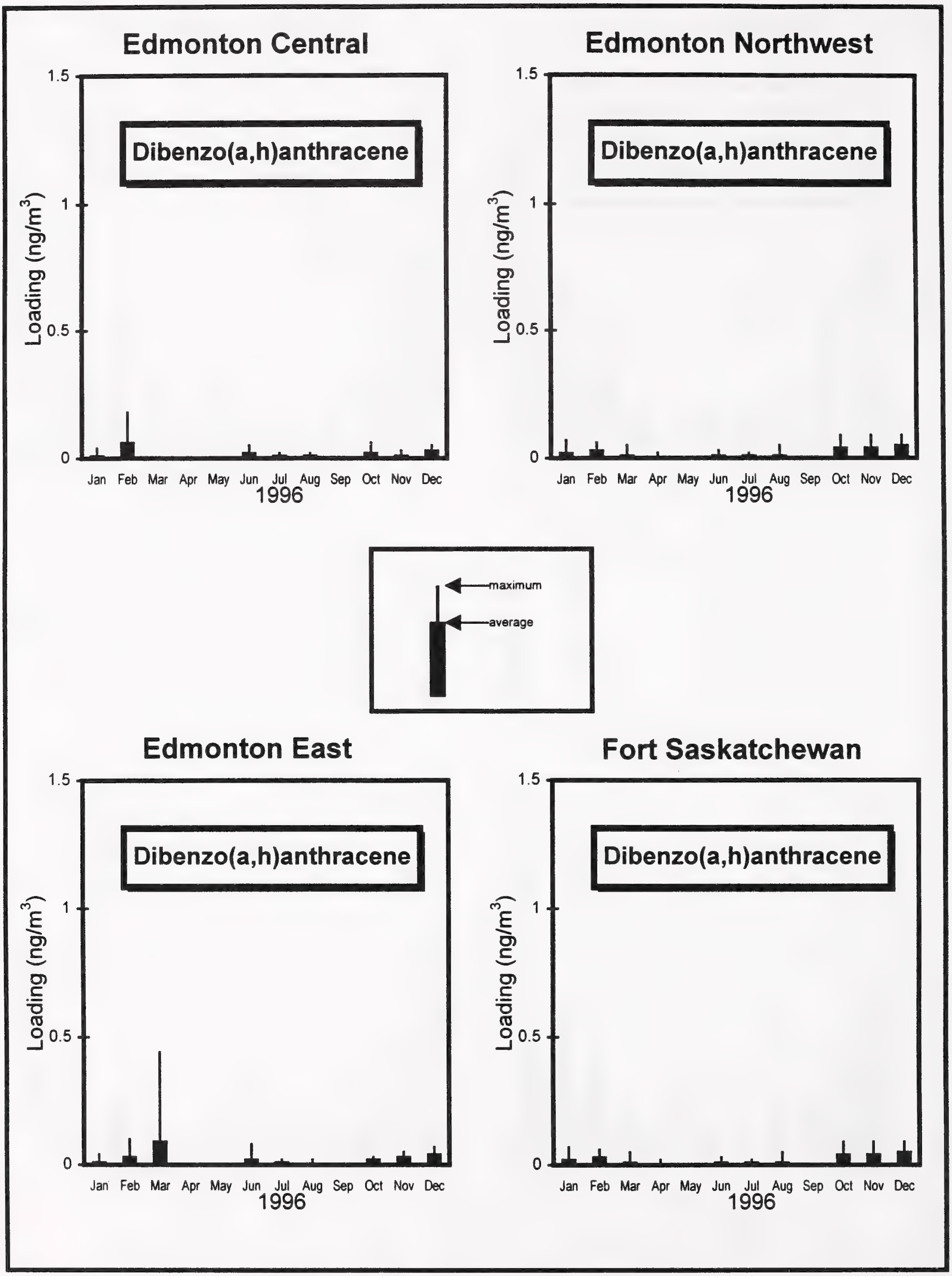


Figure 5-17 **Frequency distribution of dibenzo(a,h)anthracene loadings at Edmonton and Fort Saskatchewan**

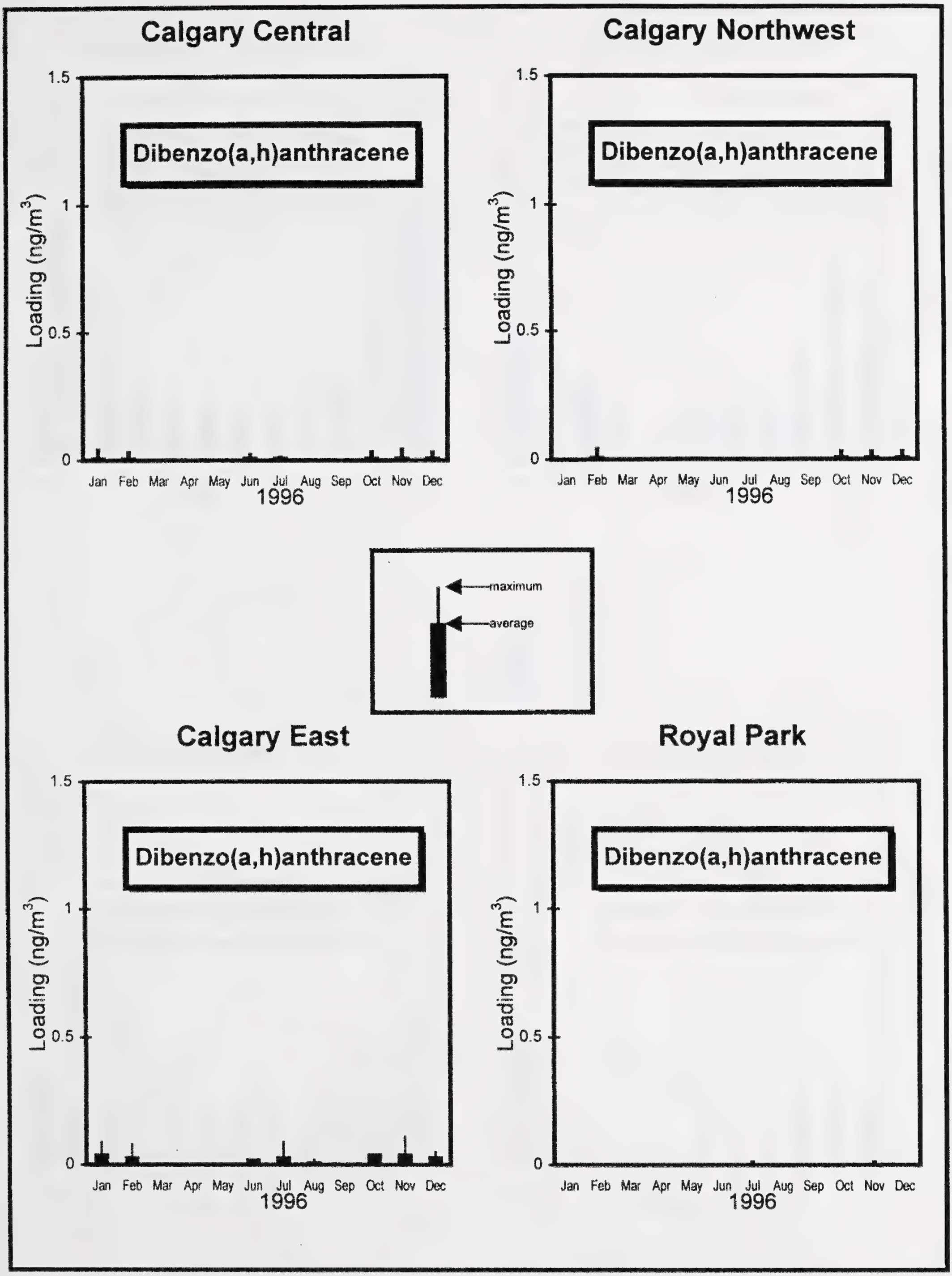


Figure 5-18 **Frequency distribution of dibenzo(a,h)anthracene loadings at Calgary and Royal Park**

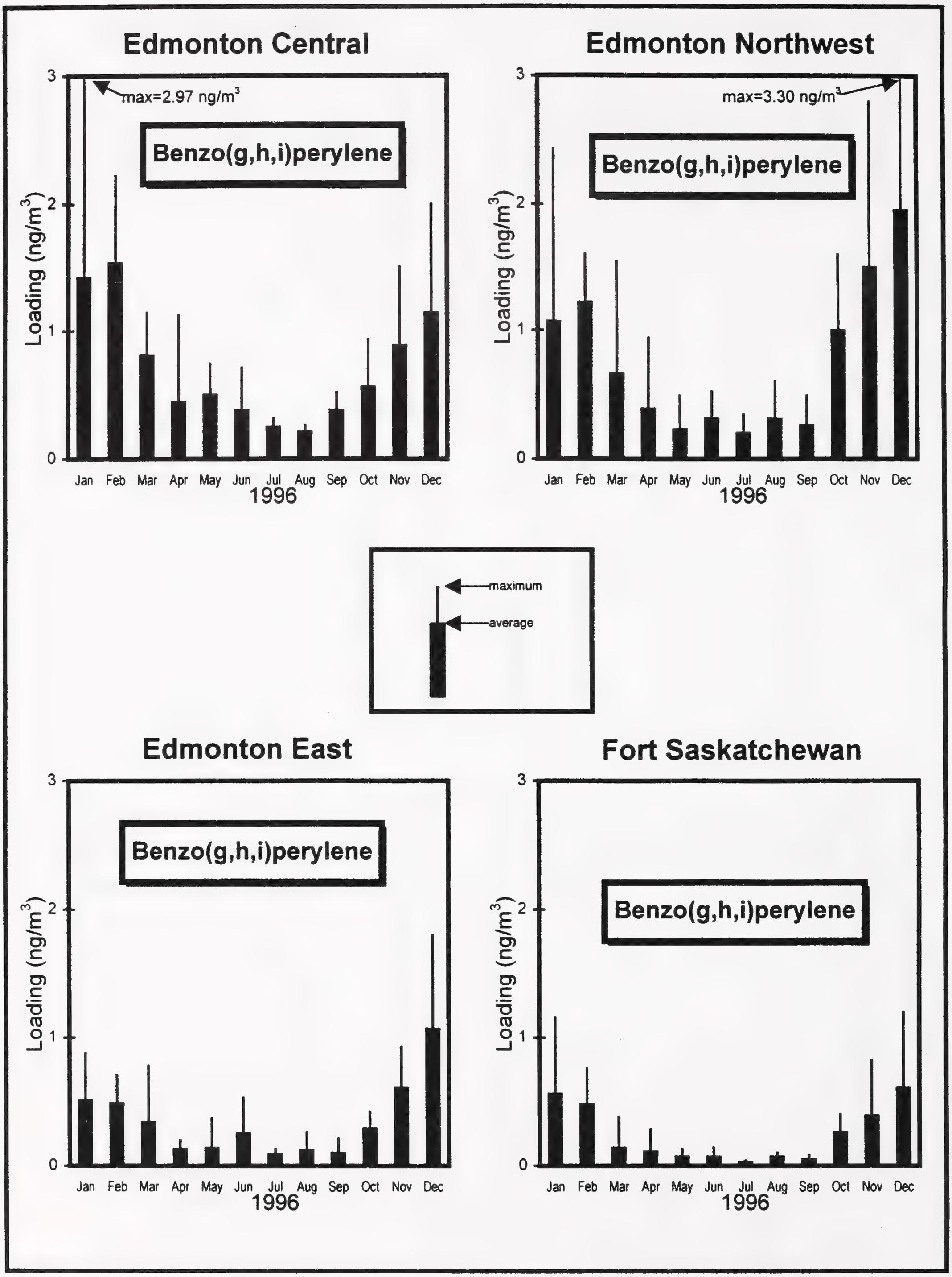


Figure 5-19 Frequency distribution of benzo(g,h,i)perylene loadings at Edmonton and Fort Saskatchewan

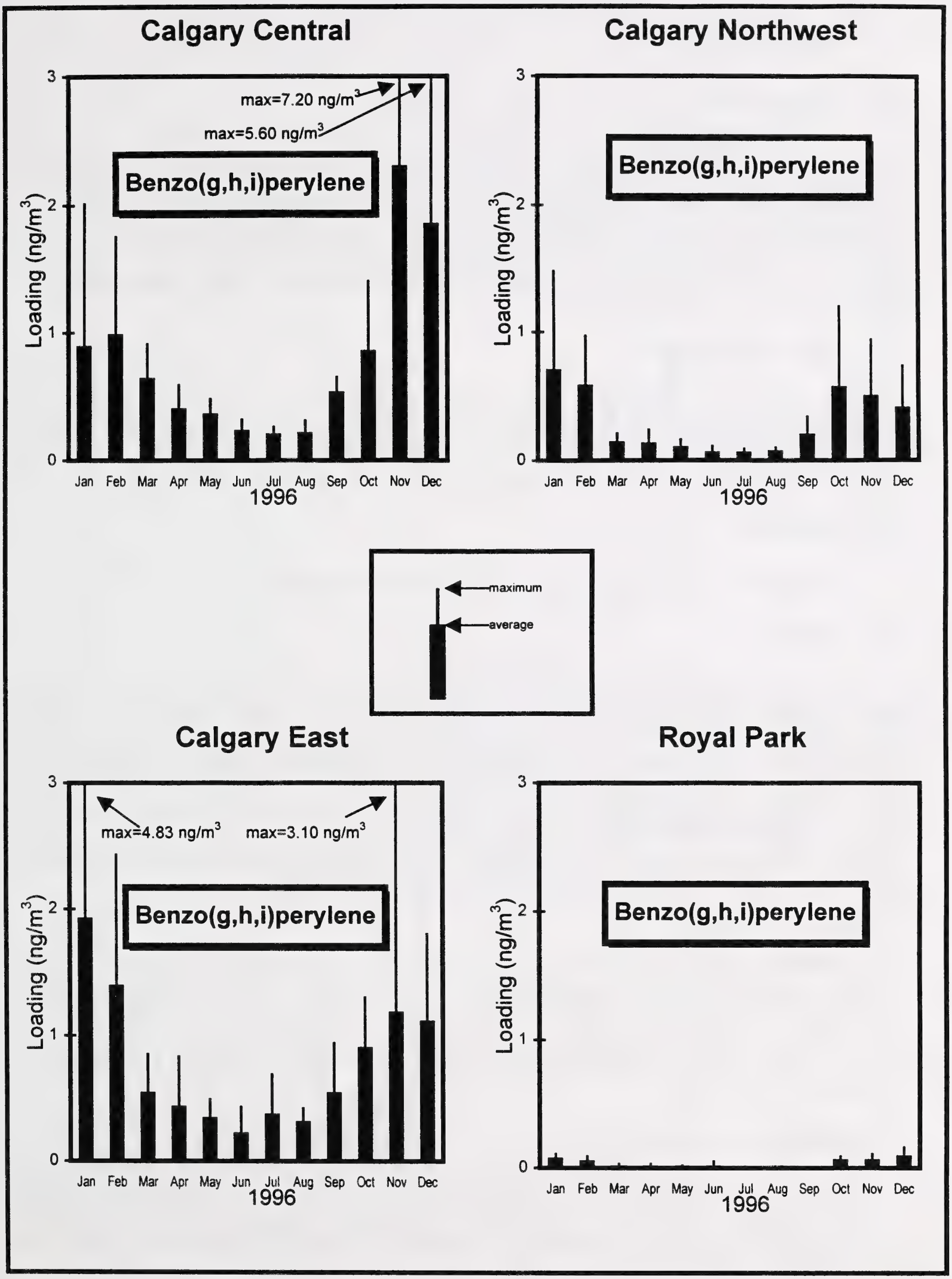


Figure 5-20 Frequency distribution of benzo(g,h,i)perylene loadings at Calgary and Royal Park

5.3 SULPHATES

5.3.1 Characteristics

Sulphate is the oxidized form of sulphur dioxide and other sulphur compounds. This oxidized ion will often be combined with other ions to form particulate sulphate. Along with nitrate and ammonia, sulphate is a primary component of acid deposition. The primary sources of sulphur dioxide and other sulphur compounds include natural gas processing facilities, oil sands facilities, power plants, oil refineries, pulp and paper mills and fertilizer plants. Natural sources of sulphur compounds include coal, natural gas, oil, sulphur hot springs, sloughs, swamps and dust from sulphur-containing rocks and soil.

5.3.2 Method of Monitoring

Sulphates are monitored every sixth day at all high-volume monitoring stations in accordance with the NAPS monitoring schedule. High-volume filters undergo laboratory analysis using ion chromatography to quantify the amount of sulphates in the sample. The result is a 24-hour accumulated loading of sulphates expressed in micrograms per cubic meter (μg/m^3).

5.3.3 Guidelines

Alberta does not have guidelines for particulate sulphate loadings.

5.3.4 Results

Sulphates were monitored at all high-volume monitoring stations in 1996. The highest annual average sulphate concentrations were recorded at the Calgary East (3.17 μg/m^3), Edmonton East (2.76 μg/m^3), and Fort Saskatchewan (2.94 μg/m^3) monitoring stations. Higher concentrations at these locations were likely due to fugitive sulphur emissions from local sources. Higher annual average sulphate values were recorded from 1993 to 1996 than from 1985 to 1987 when sulphates were monitored. This increase in sulphate concentrations may be related to improvements in analytical methods. Figures 5-21 to 5-23 show the mean, maximum and minimum sulphate loadings by month at each of the monitoring stations. Total suspended particulate samples were not analyzed for sulphates from 1988 to 1992.

➢ Edmonton

Sulphate concentrations were slightly higher at the East station than the Central and Northwest Edmonton monitoring stations. Annual average sulphate concentrations were 2.38 μg/m^3 at the Central station, 2.49 μg/m^3 at the Northwest station and 2.76 μg/m^3 at the East station. Maximum sulphate values were 10.8, 13.8, and 12.6 μg/m^3 at the Central, Northwest and East stations, respectively. These values were measured in February at all stations.

➢ Calgary

The highest average and peak sulphate loadings were recorded at the Calgary East monitoring station. Peak values of 7.4, 5.6, and 8.6 μg/m^3 were observed at the Central, Northwest, and the East stations, respectively. These high values occurred in the winter and spring months. Annual average sulphate concentrations ranged from 2.06 μg/m^3 at the Northwest station to 3.17 μg/m^3 at the East station.

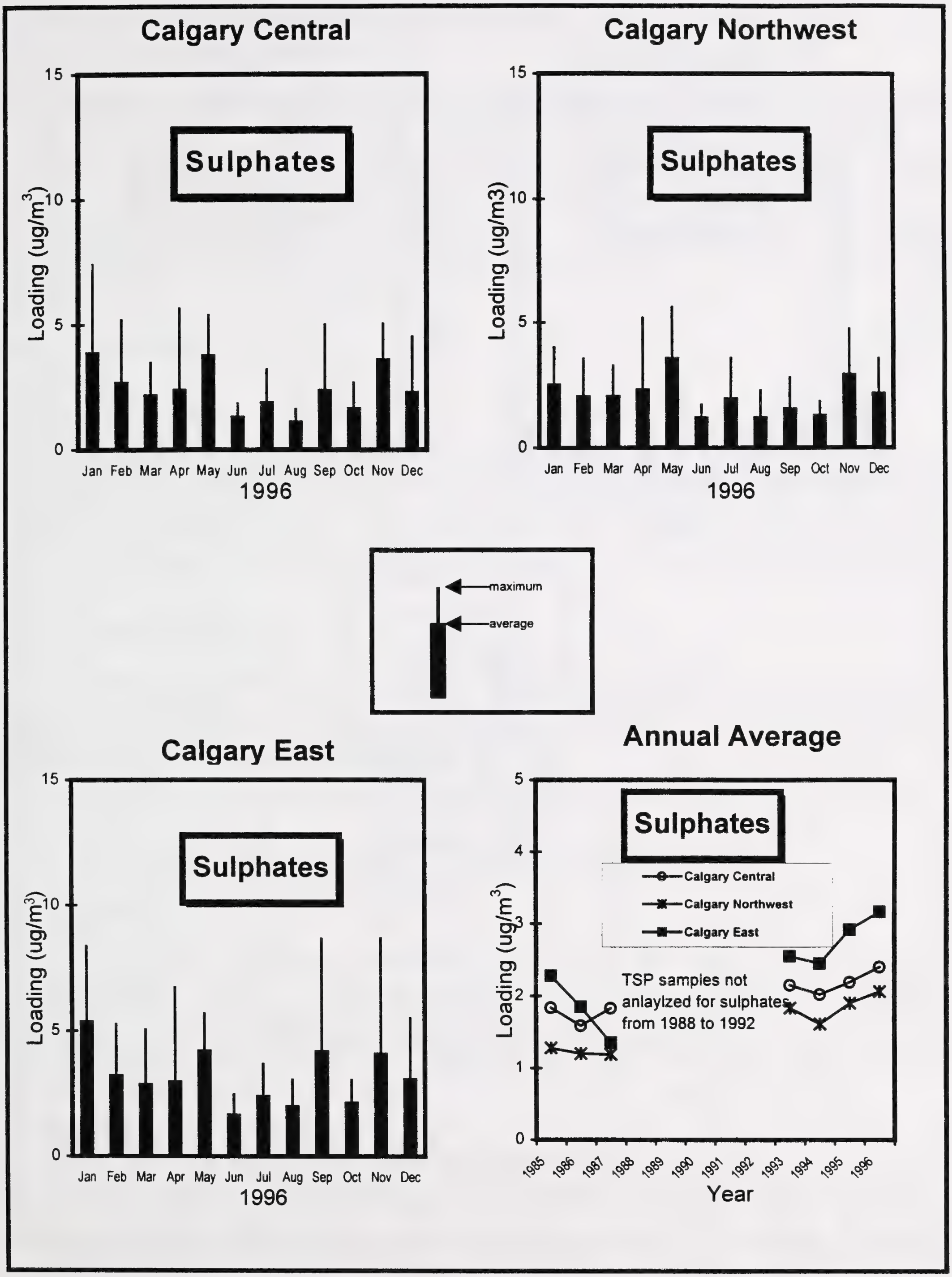


Figure 5-22 Frequency distribution of sulphate loadings at Calgary

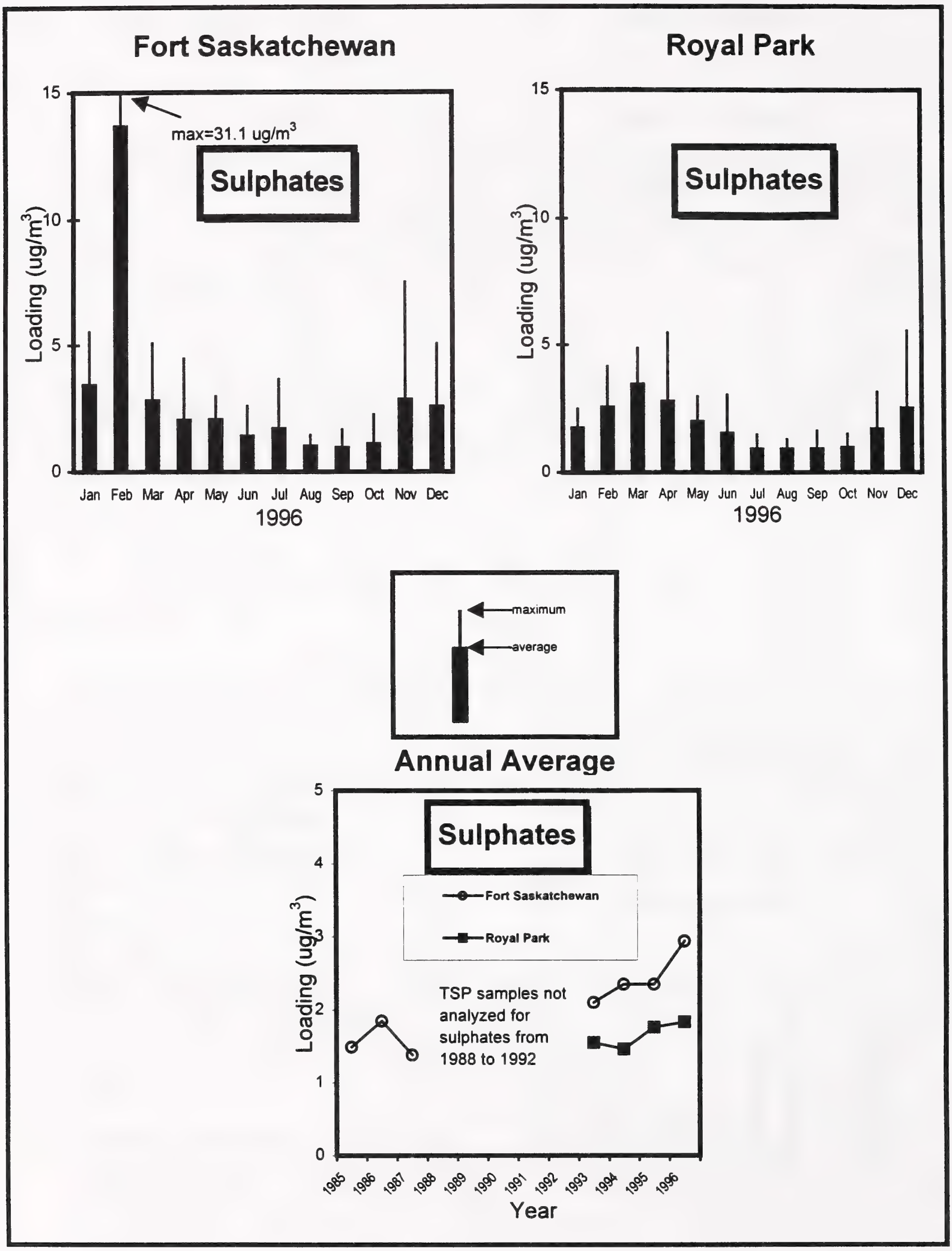


Figure 5-23 Frequency distribution of sulphate loadings at Fort Saskatchewan and Royal Park

➢ Fort Saskatchewan and Royal Park

The maximum sulphate concentration at the Fort Saskatchewan monitoring station was 31.1µg/m³. At Royal Park (10 km northwest of Vegreville), the maximum concentration of sulphate was 5.5 µg/m³. These peak values were measured in February and December at Fort Saskatchewan and Royal Park, respectively. The major sources of sulphur compounds in Fort Saskatchewan are likely local industrial facilities (fertilizer production, petroleum refining, solvent production) and natural sulphates contained in wind-blown dust. Sulphates in the Vegreville area are likely the result of wind-blown dust and possibly transport from sulphate sources in Edmonton (gasoline vehicles, diesel vehicles and industry) or the power plants located west of Edmonton.

5.4 NITRATES

5.4.1 *Characteristics*

Nitrates are oxidized forms of oxides of nitrogen (including nitrogen dioxide, nitrous oxide and nitric oxide). As with sulphate, these oxidized ions will exist in combination with other ions (cations) to form particulate nitrate. The major sources of oxides of nitrogen in Alberta are natural gas processing facilities, transportation, power plants, natural gas and heating fuel use, agricultural fuel use, forest fires, residential wood burning, fertilizer plants and nitric acid plants. Wind-blown dust and soil also contain particulate nitrate.

5.4.2 *Method of Monitoring*

Nitrates are monitored every sixth day at all high-volume monitoring stations according to the NAPS monitoring schedule. High-volume filters undergo laboratory analysis using ion chromatography to quantify the amount of nitrates in the sample. The result is a 24-hour accumulated loading of nitrates expressed in micrograms per cubic meter (µg/m³).

5.4.3 *Guidelines*

Alberta does not have guidelines for particulate nitrate loadings.

5.4.4 *Results*

Figures 5-24 to 5-26 show mean and maximum nitrate concentrations at all intermittent monitoring stations. Nitrates were monitored at all Edmonton, Calgary, Fort Saskatchewan and Royal Park monitoring stations in 1996. Annual average nitrate loadings ranged from 0.84 µg/m³ at the Royal Park station to 1.56 µg/m³ at the Calgary East monitoring station. Relatively high nitrate concentrations were also recorded at the Edmonton East (1.46 µg/m³), Edmonton Central (1.29 µg/m³), and Calgary Central (1.30 µg/m³) stations.

➢ Edmonton

In Edmonton, nitrate concentrations were highest at the East monitoring location, but relatively high at both the Central and Northwest locations. Oxides of nitrogen from vehicle exhaust are likely the major contributor to nitrates at all of these locations. Peak nitrate concentrations of 7.39, 9.96, and 9.63 µg/m³ were recorded at the Central, Northwest and East stations, respectively. These values were measured in March at the Downtown and Northwest monitoring station, and in December at the East monitoring location.

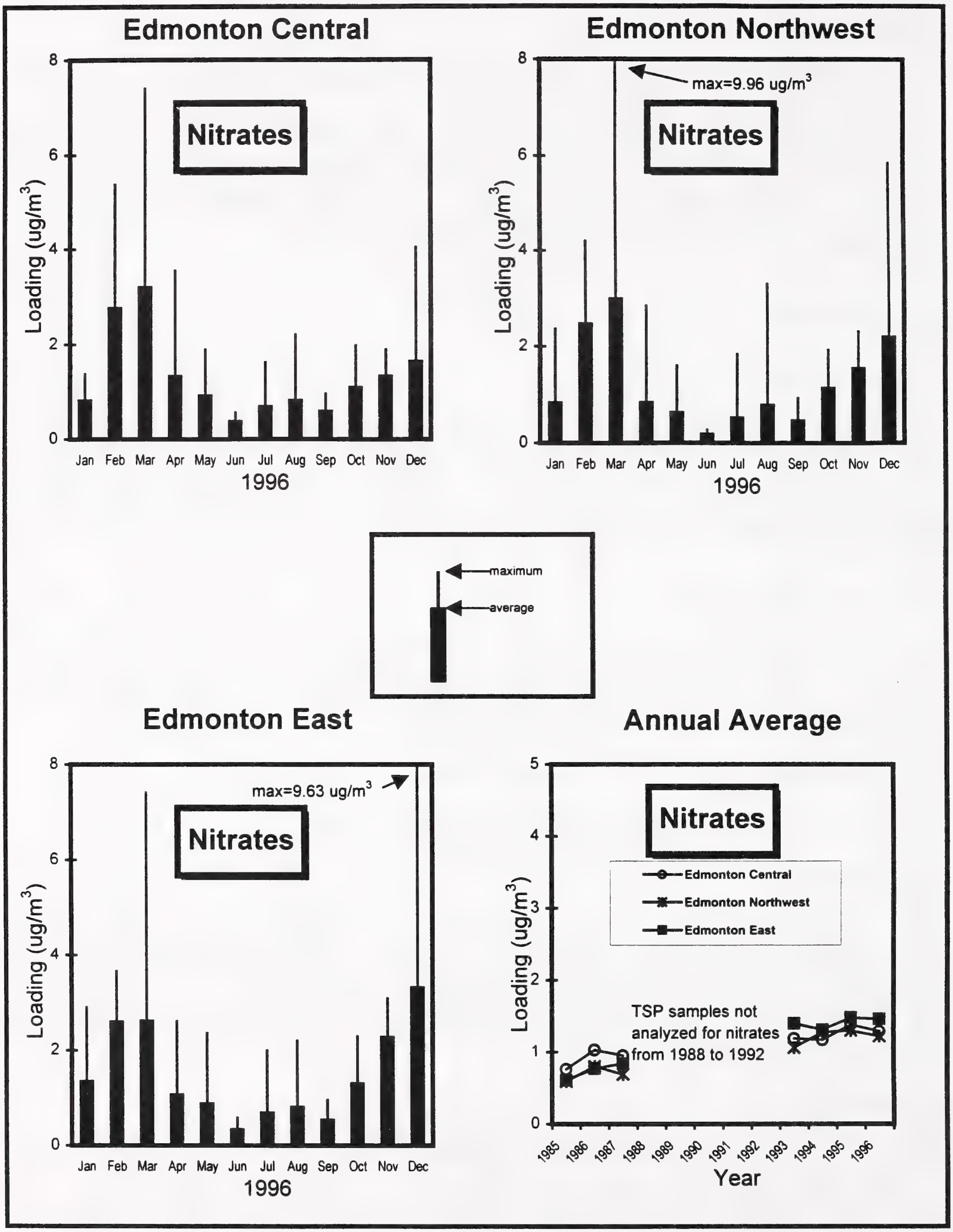


Figure 5-24 Frequency distribution of nitrate loadings at Edmonton

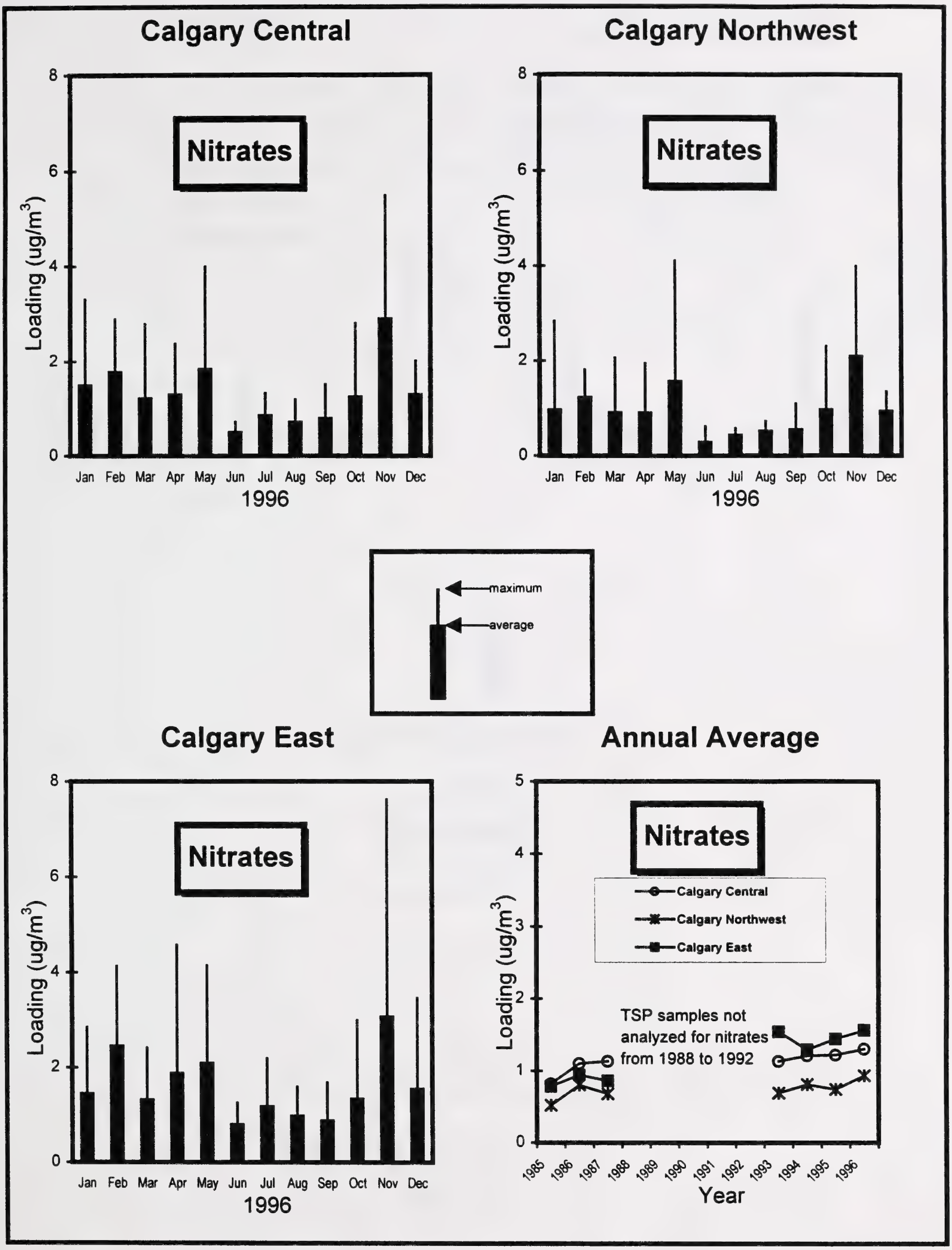


Figure 5-25 Frequency distribution of nitrate loadings at Calgary

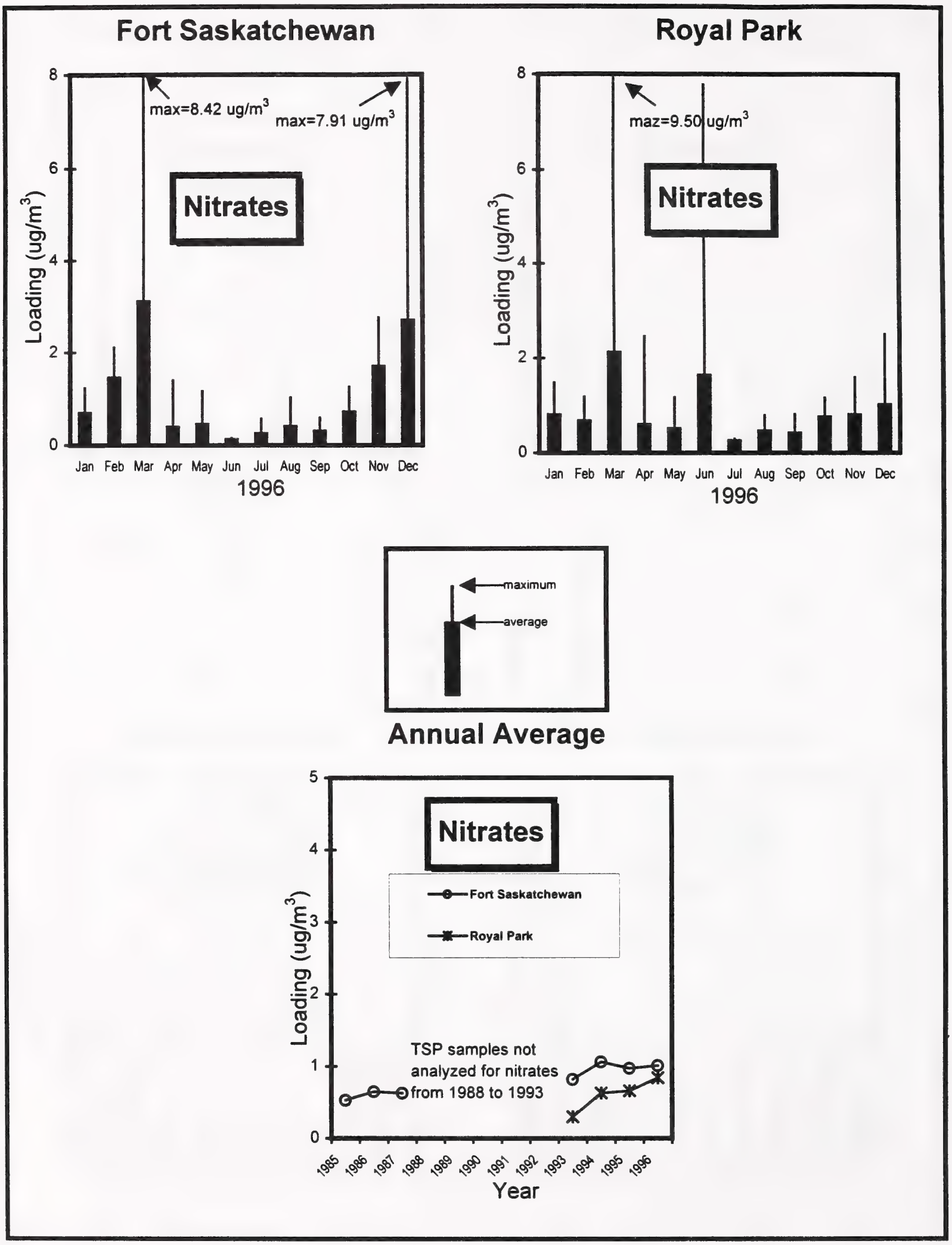


Figure 5-26 **Frequency distribution of nitrate loadings at Fort Saskatchewan and Royal Park**

➢ Calgary

Nitrate concentrations were substantially greater at the Calgary East and Central monitoring stations than the Northwest station. Peak values at the Central, Northwest and East stations were 5.49, 4.10, and 7.62 µg/m^3, respectively. These values were measured in the winter and spring months. The major sources of oxides of nitrogen in Calgary are vehicle exhaust emissions and heating fuel combustion.

➢ Fort Saskatchewan and Royal Park

The annual average nitrate loadings were 1.01 and 0.84 µg/m^3 at the Fort Saskatchewan and Royal Park locations, respectively. Relatively high maximum nitrate concentrations were recorded in March at both locations, with a maximum of 8.42 µg/m^3 at the Fort Saskatchewan station and 9.50 µg/m^3 at Royal Park. Absorption of nitrates by precipitation is at a minimum in the winter and early spring seasons.

6. STATIC MONITORING RESULTS

Static monitoring is the measurement of total accumulated loadings of pollutants on a more lengthy schedule than continuous or intermittent monitoring. In 1996, Alberta Environmental Protection conducted static monitoring at 2 locations in the province. Static monitoring was undertaken from January to December in the Fort McMurray area, and from January to June in the Raven Brood area of central Alberta. The Fort McMurray network consisted of 6 stations that monitored both total sulphation and hydrogen sulphide, while only total sulphation was monitored at the Raven Brood station. These locations are indicated in Figure 6-1.

With the exception of these two monitoring networks, static monitoring by Alberta Environmental Protection was discontinued in June, 1995. Originally, the static monitoring program was initiated in order to: (1) obtain ambient air parameter concentrations in the vicinity of industrial sources using an inexpensive monitoring method; and (2) obtain sulphation loadings representative of large urban areas such as Edmonton and Calgary. Currently, efforts are being focussed on finding techniques which will give a more accurate and meaningful representation of ambient air quality conditions in a cost-effective manner. Static monitoring methods for ozone, sulphur dioxide, nitrogen dioxide and volatile organic compounds are currently being tested (Alberta Research Council, 1995). A revised static monitoring program will be deployed once these new methods are tested under Alberta conditions.

The data are presented as monthly average loadings for each location. Daniel's Trend Test was used to determine if annual average loadings of total sulphation and static hydrogen sulphide from 1980 to 1996 showed a significant trend. (The procedure for this test is described in Section 4.)

6.1 TOTAL SULPHATION

6.1.1 Characteristics

Total sulphation includes all sulphur-containing compounds which are present in the ambient air. These compounds include hydrogen sulphide, sulphur dioxide and mercaptans. Sources of sulphur-containing compounds include emissions from sulphur recovery processes at sour gas plants and fossil fuel combustion.

6.1.2 Method of Monitoring

Total sulphation is sampled with a sulphation cylinder or a sulphation plate which has a surface that is impregnated with reactive potassium carbonate. The sulphation samplers are placed in the field to collect accumulated loadings of total sulphation for a period of one or three months. Laboratory analysis is then conducted using ion chromatography to determine the total sulphation loading.

6.1.3 Guidelines

The guideline for total sulphation loading in Alberta is:

- 0.50 mg SO_3 equivalent/day/100 cm^2 (milligrams as SO_3 per day per 100 square centimetres).

6.1.4 Results

Total sulphation was monitored as a one-month accumulated loading at both the Fort McMurray and Raven Brood networks. There were no exceedances of the guideline at any stations in 1996.

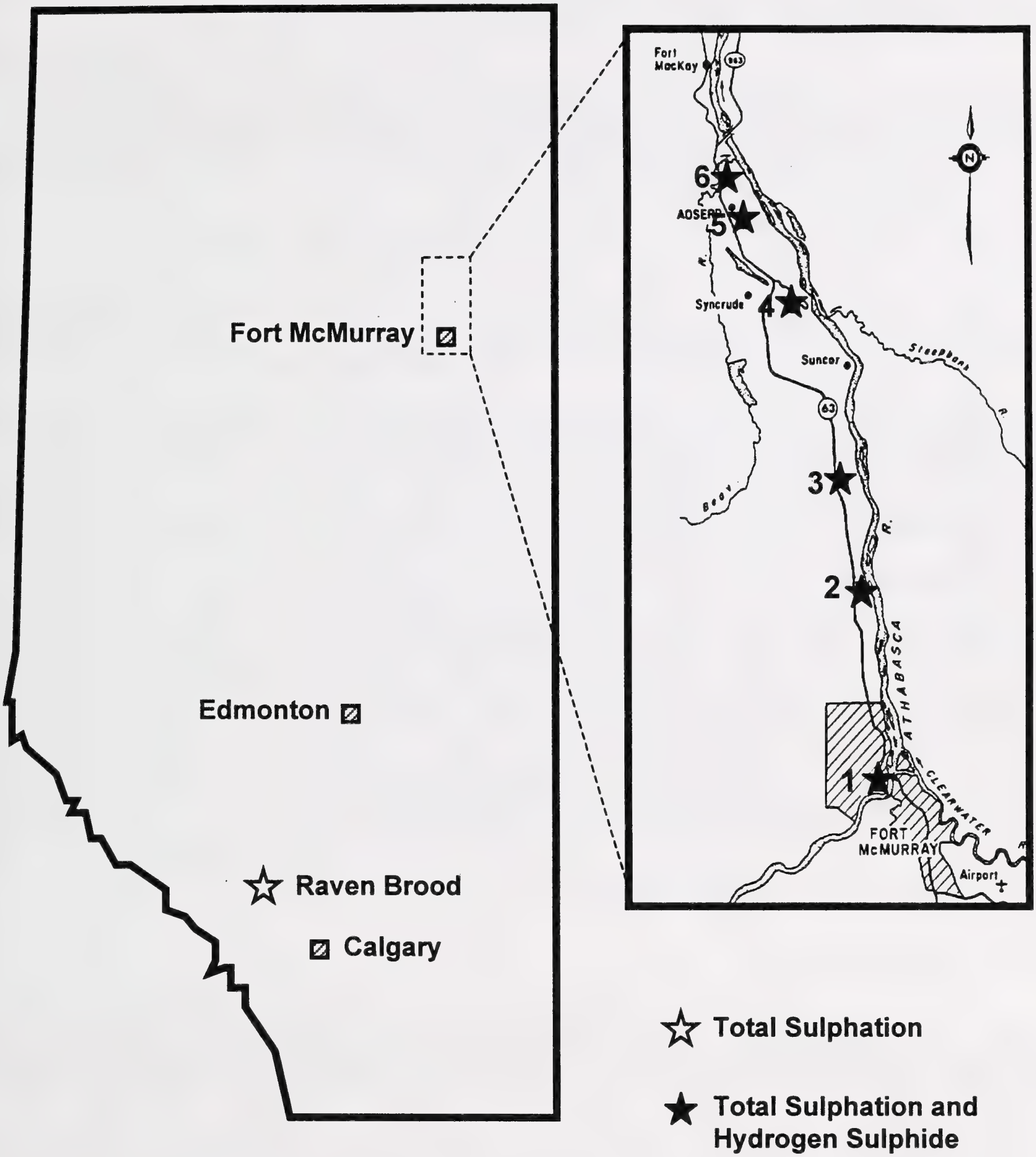


Figure 6-1 Location of static monitoring stations in 1996

Average total sulphation values were 0.042 mg/day/100 cm^2 at Fort McMurray, and 0.018 mg/day/100 cm^2 at Raven Brood. The maximum total sulphation loadings from these networks were 0.218 and 0.025 mg/day/100 cm^2, at the Fort McMurray and Raven Brood stations, respectively. These values are about 44% and 5% of the guideline for total sulphation (0.5 mg/day/100 cm^2), respectively. Total sulphation was only monitored from January to June at the Raven Brood station.

Average total sulphation loadings ranged from 0.025 mg/day/100 cm^2 at the Fort McMurray station #2 to 0.077 mg/day/100 cm^2 at the Fort McMurray station #4. The maximum monthly concentration of 0.218 mg/day/100 cm^2 was recorded in March at station #4. This value is 44% of the guideline for total sulphation. The monthly static monitoring results for total sulphation at the Fort McMurray monitoring stations and for the Raven Brood station are listed in Table 6-1.

Table 6-1 Static monitoring results for total sulphation in 1996 (mg/day/100 cm^2).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Fort McMurray # 1	0.029	0.085	0.095	0.061	0.020	0.018	0.018	<0.016	0.038	0.019	<0.016	<0.016	0.037
Fort McMurray # 2	<0.016	0.053	0.067	0.032	<0.016	0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	0.025
Fort McMurray # 3	0.028	0.123	0.168	0.119	0.036	0.068	0.040	0.019	0.025	0.021	0.025	<0.016	0.057
Fort McMurray # 4	0.087	0.070	0.218	0.122	0.170	0.040	0.072	0.050	0.023	0.034	0.017	0.020	0.077
Fort McMurray # 5	0.019	0.036	0.042	0.041	0.031	<0.016	0.019	0.024	<0.016	0.021	<0.016	<0.016	0.030
Fort McMurray # 6	0.020	0.016	0.055	0.056	0.038	<0.016	0.045	0.027	0.043	0.024	<0.016	<0.016	0.031
Fort McMurray Average (# 1-6)	0.033	0.064	0.107	0.072	0.052	0.029	0.035	0.025	0.027	0.023	0.018	0.017	0.042
Raven Brood	0.016	0.017	0.025	0.016	0.016	0.016	n/a	n/a	n/a	n/a	n/a	n/a	0.018

n/a no data available (Raven Brood decommissioned after June 30, 1996)
<0.016 total sulphation loading was less than the detection limit of 0.016 mg/day/100cm^2

6.2 HYDROGEN SULPHIDE (H_2S)

6.2.1 *Characteristics*

The characteristics of H_2S are described in Section 4.6 of this report. Industrial sources of H_2S include petroleum refining plants, natural gas plants, petrochemical complexes, coke oven plants, and pulp and paper mills employing the kraft pulping process. H_2S occurs naturally in coal, natural gas, oil, sulphur hot springs, sloughs, swamps and lakes.

6.2.2 *Method of Monitoring*

H_2S is monitored by using an exposure cylinder with a surface that has been impregnated with zinc acetate. H_2S reacts with zinc acetate to form zinc sulphide. The quantity of zinc sulphide is proportional to the quantity of H_2S deposited onto the surface. Laboratory analysis of the samples is conducted using iodometric titration.

6.2.3 Guidelines

The guideline for static H_2S loading in Alberta is:

- 0.10 mg SO_3 equivalent/day/100 cm^2 (milligrams as SO_3 per day per 100 square centimetres).

6.2.4 Results

H_2S was monitored on a one-month basis at six stations in the Fort McMurray area. The guideline of 0.10 mg SO_3/day/100 cm^2 for static H_2S was not exceeded at this location in 1996. Average static H_2S loadings ranged from 0.007 mg/day/100 cm^2 at the Fort McMurray stations #2, #5 and #6 to 0.010 mg/day/100 cm^2 at station #4. The maximum monthly concentration of 0.034 mg/day/100 cm^2 occurred in March at the Fort McMurray monitoring station #3. This value is 34% of the guideline for static hydrogen sulphide. Based on data from 1980 to 1995, no significant trend is evident at the Fort McMurray network. Monthly monitoring results for static hydrogen sulphide at the Fort McMurray monitoring stations are given in Table 6-2.

Table 6-2 Static monitoring results for hydrogen sulphide in 1996 (mg/day/100 cm^2).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Fort McMurray # 1	<0.004	0.025	0.025	<0.004	0.009	<0.004	0.009	<0.004	0.005	<0.004	<0.004	<0.004	0.008
Fort McMurray # 2	<0.004	0.023	0.020	<0.004	<0.004	<0.004	0.004	<0.004	0.005	<0.004	<0.004	<0.004	0.007
Fort McMurray # 3	n/a	0.021	0.034	0.009	<0.004	<0.004	<0.004	<0.004	0.005	<0.004	0.005	<0.004	0.009
Fort McMurray # 4	<0.004	0.030	0.031	<0.004	<0.004	<0.004	<0.004	<0.004	0.005	<0.004	0.009	0.014	0.010
Fort McMurray # 5	<0.004	0.025	0.015	0.004	<0.004	<0.004	0.004	<0.004	<0.004	0.006	<0.004	<0.004	0.007
Fort McMurray # 6	<0.004	0.012	0.025	<0.004	<0.004	<0.004	<0.004	<0.004	0.005	0.004	0.009	<0.004	0.007
Average (#1-6)	<0.004	0.023	0.025	0.005	0.005	<0.004	0.005	<0.004	0.005	<0.004	0.006	0.006	0.008

n/a	no data for this month
<0.004	total sulphation loading was less than the detection limit of 0.004 mg/day/100cm^2

7. PRECIPITATION QUALITY MONITORING RESULTS

7.1 *Characteristics*

There is an increasing public awareness of the occurrence and effects of acidic substances in the atmosphere. Acidic substances contained in the atmosphere will eventually be deposited on the earth's surface in the form of precipitation (wet deposition or acid precipitation) or particulates and gases (dry deposition).

The effects of acid deposition vary depending on the amount of acidic pollutants being deposited and the buffering capacity (ability of soil or water to neutralize the acidity of the precipitation) of the receptor. In eastern North America and western Europe, changes in aquatic life, changes to forest and crop growth, and damage to buildings and equipment have been attributed to acid deposition.

Precipitation samples have been collected by the Alberta Government provincial monitoring network since 1978. The objectives of the acid precipitation program are to: (1) monitor the quality of precipitation; (2) detect any significant trends in precipitation quality; and (3) determine long-range transport of pollutants into the province.

7.2 *Method of Monitoring*

Precipitation is collected by a sampler that opens automatically when precipitation (rain or snow) occurs and closes when the precipitation ceases. Each week, if sufficient precipitation occurs, the sample is retrieved from the field and sent to the laboratory for analysis. Data obtained from this analysis includes pH, strong acidity, total acidity, specific conductance, major cations (calcium, ammonium, sodium, magnesium and potassium) and major anions (sulphate, nitrate, chloride and phosphate).

Precipitation pH and acidity are determined using electrometric or Gran's Plot titration laboratory analytical methods. Concentrations of most anions and cations contained in the precipitation samples are determined using ion chromatography. The specific conductance of the samples are obtained from a conductivity meter.

7.3 *Guidelines*

Wet sulphate deposition is often used as an indicator of acidic wet deposition. In eastern Canada, the relationship between hydrogen and sulphate ions is strong enough to establish a basis for wet deposition objectives. An objective of 20 kg/ha/yr (kilograms per hectare per year) has been adopted for wet sulphate deposition in eastern Canada. In western Canada, it has been shown that the hydrogen-sulphate ion relationship is not strong enough to use as a basis for wet deposition standards (Lau 1982; Sandhu and Blower 1986; Bertram et al. 1987; Legge 1988). Other ions such as calcium and magnesium are associated with sulphate ions to form non-acidifying substances such as calcium sulphate and magnesium sulphate. Alberta Environmental Protection is currently exploring alternate approaches for determining target loading objectives for acidic deposition. Two approaches presented in this report are: (1) effective acidity; and (2) potential acid input.

7.4 *Results*

The locations of Alberta Environmental Protection precipitation monitoring stations are indicated in Figure 7-1. Precipitation data was collected on a weekly basis at all precipitation quality monitoring stations in 1996. Samples which remain in the field for a longer period of time (i.e. one month as compared to one week) will generally have higher pH values and higher concentrations of some other ions (Lau 1990). This is due to chemical reactions which take place in the field during the sampling period. Based on this observation, it is important to emphasize that monthly and weekly pH, ion deposition rates and effective acidity deposition rates are not directly comparable.

For the purpose of obtaining annual pH values, volume weighted average hydrogen ion concentrations from weekly samples were calculated. Annual anion, cation, effective acidity and potential acid input deposition rates were also calculated. Precipitation depths used in calculating wet deposition, effective acidity and potential acid input values were estimated using the volume of precipitation collected in each sample. Wet deposition rates are presented in units of kilograms per hectare which essentially is the total mass of a specific contaminant deposited onto one hectare during the monitoring period by precipitation. Effective acidity and potential acid input are presented as kilograms of hydrogen ion equivalents per hectare. Greater than or equal to 75% of data must be available to compute representative annual wet deposition rates. Table 7.1 shows: (1) volume-weighted average pH values; (2) the calculated effective acidity and potential acid input deposition rates; and (3) anion and cation wet deposition rates for daily, weekly and monthly precipitation samples.

7.4.1 pH

The term "acid rain" refers to precipitation with a pH value lower than what is considered normal in the background, natural environment. In theory, precipitation is slightly acidic (pH of 5.6) due to the presence of carbon dioxide. However, measurements of precipitation at remote locations have shown that the pH of uncontaminated rain is between 5.0 and 5.6 (Galloway et al., 1982; Sequeira, 1981). When pollutants such as sulphur oxides and nitrogen oxides are emitted into the atmosphere, sulphates and nitrates are formed through oxidation. Sulphates and nitrates combine with water vapour to form sulphuric and nitric acids. The presence of these acids causes precipitation to become more acidic (lower pH) which is commonly referred to as acid rain or snow.

The most acidic precipitation in 1996 was reported at the Fort McMurray station where a volume weighted average pH value of 4.9 was recorded from weekly samples. The highest pH values were recorded at the Calgary, Cold Lake, and Royal Park precipitation quality stations, with annual averages of 5.6, 5.5, and 5.5, respectively. Annual average pH values between 5.0 and 5.4 were recorded at the remaining precipitation quality stations based on annual averages of weekly data. The lowest weekly precipitation pH value was recorded at Fort McMurray with a minimum value of 4.3 in July. The highest pH value recorded was 7.5 recorded in October at the Beaverlodge station.

7.4.2 Anion Deposition (sulphate, nitrate, chloride and phosphate)

Anions are negatively charged groups of atoms or molecules formed when chemicals dissociate in water. Sulphuric acid and nitric acid produce sulphate and nitrate anions, respectively, and these are often used as a measure of acidity. Parent chemicals may be emitted into the atmosphere by gas plants, oil sands plants, coal-fired power plants, oil refineries, pulp and paper mills, fertilizer plants and agricultural activities.

Annual anion wet deposition rates were calculated as the sum of weekly deposition rates. The highest wet sulphate deposition rates occurred at Calgary in 1996, with an annual value of 4.2 kg/ha/yr, and at Red Deer with a value of 4.1 kg/ha/yr. Sulphate deposition rates greater than 4 kg/ha/yr were not recorded at any other precipitation quality monitoring station. The lowest wet sulphate deposition value of 1.8 kg/ha/yr was recorded at the Suffield station.

A maximum nitrate wet deposition rate of 3.3 kg/ha/yr was recorded at the Calgary precipitation quality station. The second highest nitrate deposition value was measured at the Cold Lake and Red Deer stations (3.1 kg/ha/yr). The lowest weekly wet nitrate deposition values were recorded at the Beaverlodge (1.7 kg/ha/yr) precipitation monitoring station.

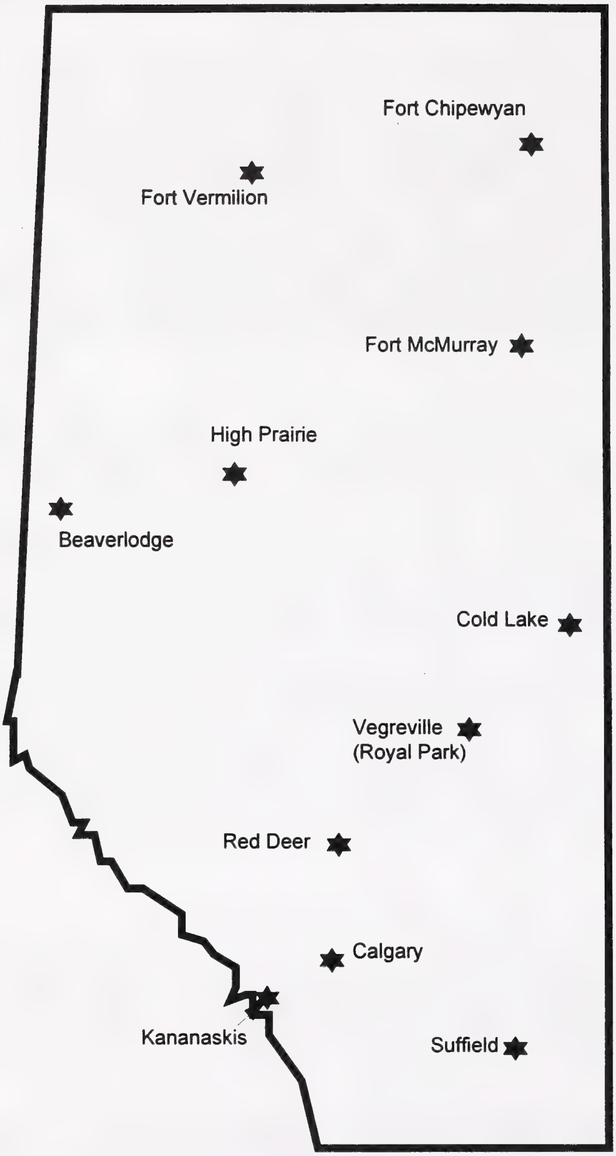


Figure 7-1 Location of precipitation quality monitoring stations in 1996.

Table 7.1 pH, effective acidity, potential acid input and wet deposition rates of precipitation at monitoring stations which collected samples on a weekly basis in 1996

Station	pH	Effective Acidity (kg/ha of eq. H+)	Potential Acid Input (kg/ha of eq. H+)
Beaverlodge	5.01	0.04	0.06
Calgary	5.59	0.08	0.10
Cold Lake	5.52	0.05	0.09
Fort Chipewyan	5.31**	**	**
Fort McMurray	4.86	0.07	0.09
Fort Vermillion	n.d.	n.d.	n.d.
High Prairie	5.30**	**	**
Kananaskis	5.09	0.06	0.10
Red Deer	5.31	0.07	0.12
Vegreville (Royal Park)	5.54	0.07*	0.10*
Suffield	5.28	0.03	0.05

Station	Anions (kg/ha)				Cations (kg/ha)				
	$SO_4^{=}$	NO_3^-	Cl^-	$PO_4^{=}$	Ca^{++}	NH_4^+	Na^+	Mg^{++}	K^+
Beaverlodge	2.5	1.7	0.3	0.0	0.6	0.5	0.2	0.2	0.1
Calgary	4.4	3.3	0.5	0.0	2.0	1.7	0.3	0.4	0.1
Cold Lake	2.7	3.1	0.3	0.1	1.2	1.3	0.3	0.3	0.1
Fort Chipewyan	**	**	**	**	**	**	**	**	**
Fort McMurray	3.9	2.3	0.4	0.0	0.8	0.6	0.2	0.2	0.1
Fort Vermillion	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
High Prairie	**	**	**	**	**	**	**	**	**
Kananaskis	3.4	2.8	0.4	0.0	1.0	0.9	0.2	0.2	0.1
Red Deer	3.8	3.1	0.3	0.0	1.2	1.4	0.1	0.2	0.1
Vegreville (Royal Park)	2.9*	2.8*	0.2*	0.0*	1.2	1.4	0.1	0.2	0.1
Suffield	1.8	2.2	0.2	0.0	0.9	0.7	0.1	0.2	0.1

* between 70-75% of data available

** less than 50% of data available

n.d. no data available from the Fort Vermilion station in 1996.

Chloride deposition rates ranged from 0.2 kg/ha/yr at the Royal Park and Suffield stations, to 1.7 kg/ha/yr at the Calgary station in 1996. Phosphate deposition values were also very low with annual totals close to the analytical detection limit. The highest annual phosphate wet deposition value was recorded at Cold Lake (0.1 kg/ha/yr).

7.4.3 Cation Deposition (calcium, ammonium, sodium, magnesium and potassium)

Cations are positively charged groups of atoms or molecules formed when chemical compounds dissociate in water. All solutions are electronically neutral and, therefore, each anion will be balanced by a cation. Many parent chemicals will emanate from industrial sources such as iron, steel, wood, coal and cement manufacturing. A large percentage of cations will also be contained in wind-blown soil and dust. The annual wet deposition rates reported here are the sum of deposition rates obtained from weekly samples.

The maximum wet calcium deposition rate occurred at the Calgary station where an annual value of 2.0 kg/ha/yr was recorded. Annual total calcium deposition values of less than 1 kg/ha/yr were measured at the Beaverlodge, Fort McMurray, and Suffield monitoring stations.

A maximum annual ammonium wet deposition rate of 1.7 kg/ha/yr was recorded at the Calgary precipitation quality station. Minimum values were observed at the Beaverlodge (0.5 kg/ha/yr), Fort McMurray (0.6 kg/ha/yr), and Suffield (0.7 kg/ha/yr) precipitation quality stations.

Wet sodium, magnesium and potassium deposition rates were less than 1 kg/ha/yr at all precipitation monitoring stations. A maximum annual sodium wet deposition rate of 0.7 kg/ha/yr was recorded at Red Deer. Wet magnesium deposition had a maximum value of 0.4 kg/ha/yr at the Calgary station. The annual potassium wet deposition rates were 0.1 kg/ha/yr at all monitoring locations.

7.4.4 Effective Acidity

Effective acidity is an approach which has been developed to estimate the degree of acidification which soil would experience as a result of atmospheric inputs. This approach takes into account: (1) direct deposition of acids onto the soil; and (2) the chemical, biological and physical processes which take place within the soil as a result of acid deposition. Effective acidity is described by the equation:

$$EA = [H^+] + 1.15x[NH_4^+] - 0.7x[NO_3^-]$$

where $[H^+]$, $[NH_4^+]$ and $[NO_3^-]$ are concentrations of hydrogen ions, ammonia ions and nitrate ions, respectively, expressed as molar equivalents (Coote et al, 1981). The hydrogen ion concentration is a measure of acidic compounds deposited directly to the soil. The terms $1.15x[NH_4^+] - 0.7x[NO_3^-]$ indicate the estimated effect of wet ammonia and nitrate deposition which indirectly generate acidity in the soil.

When ammonia is nitrified (converted to nitrate), volatized (lost to the atmosphere), fixed or taken up by plants, the net effect is an increase in hydrogen ion concentration and, therefore, an increase in the acidity of the soil. The processes of denitrification, nitrate leaching and plant uptake of nitrate lead to a net reduction of the hydrogen ion concentration and, therefore, a net decrease in the acidity of the soil. The effective acidity equation takes into account the relationship between these processes within the soil. It is important to note that the calculations presented here reflect the effective acidity calculated from wet deposition. It is expected that the contribution of dry deposition is at least 40% of total deposition. In Table 7.1, annual effective acidity deposition rates are the sum of weekly deposition rates.

Effective acidity deposition rates range from 0.03 kg(of H^+)/ha/yr at the Suffield station to 0.08 kg(of H^+)/ha/yr at the Calgary precipitation quality station. These values are comparable to long-term (1978 to 1990) average effective acidity deposition values presented by Peake and Wong (1992). Long term average effective acidity deposition rates range from 0.04 kg/ha/yr at High Prairie, High Level and Lethbridge to 0.19 kg/ha/yr at Suffield.

7.4.5 Potential Acid Input

The potential acid input into a ecosystem has been calculated using the method that has been applied in European countries (Lovblad et al., 1992; Bull, 1992). This method takes into account all sulphur and inorganic nitrogen deposited by wet and dry deposition processes. The non-marine base cation deposition is subtracted from the equation to get the net acid input into the ecosystem. Potential acid input is calculated using the following equation:

potential acid input = sulphur deposition + nitrogen deposition - base cation deposition

where sulphur deposition is the sum of sulphate and sulphur dioxide; nitrogen deposition is the sum of nitrate, nitric acid, nitrogen dioxide, ammonium and ammonia; and base cation deposition is the sum of calcium, magnesium and potassium (Maynard, 1996). All values are calculated in equivalent kilomoles of hydrogen ions per hectare per year. For wet deposition, potential acid input is calculated using sulphate, nitrate, ammonium, calcium, magnesium and potassium concentrations in precipitation.

Potential acid input values were slightly higher than effective acidity values at all stations. A maximum potential acid input value of 0.13 kg(of H^+)/ha/yr was calculated for the Red Deer station. Values less than or equal to 0.10 kg(of H^+)/ha/yr were recorded at the remaining precipitation quality stations. The lowest annual potential acid input deposition rate was recorded at the Suffield station where a value of 0.05 kg(of H^+)/ha/yr was calculated.

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